RESPONDING TO THE MATHEMATICS PROBLEM:

The Implementation of Institutional Support Mechanisms

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Supported by:

The Wilkinson Charitable Trust

The Higher Education Academy Maths, Stats & OR Network

centre for excellence sigma in mathematics & statistics support

Published by the Maths, Stats & OR Network
May 2010

ISBN 978-0-9555914-6-4

Christie dedicates this volume to her darling Poppy, who, at the time of publishing, has mastered counting up to 10.

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PREFACE

This volume arose from a conference, *Addressing the Quantitative Skills Gap: Establishing and Sustaining Cross-Curricular Mathematical Support in Higher Education*, held at the University of St Andrews in 2007. The aim of that conference, and of this volume of collected essays, is to explore the logistics and economics of establishing and sustaining institution-wide mathematics support provision.

We explore a range models for delivering mathematical support accommodating an even wider range of budgets. Additionally, we identify how universities can call upon their maths support provision to demonstrate that they are addressing institutional agendas including quality enhancement, employability and skills, the first year experience, flexible delivery, retention, and the student learning experience. Looking to the future we note how mathematics support has broadened from its original focus on the STEM subjects and discuss how emerging technologies are being exploited for its provision.

ACKNOWLEDGMENTS

The editors are truly grateful for the generous support of the Maths, Stats and OR Network, The Wilkinson Charitable Trust, **sigma**, and the University of St Andrews without which this volume would never have been produced. Additionally, for his wise council, love and support, not to mention hours spent proof reading, Christie would like to give particular thanks to Dr Alexander Marr. Without his encouragement she would never have ventured into the world of mathematics support.

Finally, we would like to thank the following for their help, encouragement and support:

Jayne Callum

Prof. Tony Croft

Margaret Hall

Brad Hodgson

Prof. Celia Hoyles

Glenn Hurstfield

Chantal Jackson

Dr Joe Kyle

Prof. Duncan Lawson

Barry Lock

Chris Morgan

Carol Morris

Janet Nuttall

Moira Petrie

Prof. Ron Piper

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Prof. Russell Rimmer, *Queen Margaret University*

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Prof. Rebecca Taylor, *Nottingham Trent University*

PRELIMINARIES

Introduction and Keynote Speeches

Introduction

C. M. Marr & M. J. Grove

In June 2007, a conference entitled *Addressing the Quantitative Skills Gap: Establishing and Sustaining Cross-Curricular Mathematical Support in Higher Education* was held at the University of St Andrews. The conference, attended by 42 interested parties from Government and universities across the UK, brought together both those with expertise and experience in delivering mathematics support, and those charged with investigating the practical issues surrounding the establishment of mathematics support within their own institutions. As such, the aim of the conference was not to consider the delivery of mathematical content, but rather to explore the logistics and economics of establishing and sustaining institution-wide mathematics support provision. This volume, *Responding to the Mathematics Problem: the Implementation of Institutional Support Mechanisms* is a record of that event.

There has been a tendency to view mathematics support as remedial, targeting the less able student. The St Andrews conference sought to redress the balance and emphasise the benefits and importance of mathematics support provision for students of all abilities. Additionally, it sought to articulate how mathematics support can address institution-wide agendas such as quality enhancement, employability and skills, the first year experience, flexible delivery, and the student learning experience. In so doing, it also demonstrated how institutions could begin to tackle the challenges of student retention and widening participation.

The idea of mathematics support is not a new one. In May 1999 a meeting took place at the Moller Centre, Cambridge, attended by 35 participants from a range of HEIs within the UK. Few of those involved could have been aware of the impact of the report that followed from this landmark meeting: Trevor Hawkes and Mike Savage's *Measuring the Mathematics Problem* (Hawkes & Savage, 2000). This report identified the issues facing Mathematics, Physics and Engineering departments within the UK, highlighted a number of major concerns, and recommended ways to address those concerns:

> *"Prompt and effective support should be available to students whose mathematical background is found wanting."*

One of the first attempts to measure the effectiveness of mathematics support provision was made in 1994 by Ian Beveridge, then of Luton University. He described a 'workshop' approach used for supporting students taking the Access to Higher Education Diploma (Beveridge, 1994). Approximately 7 years later, a survey by Lawson, Halpin and Croft (Lawson, Halpin & Croft, 2001) found that of the 95 responding UK HEIs, 46 (48%) had some form of mathematics support provision. In a follow-up survey (Perkin & Croft, 2004), it was found that of the responding 101 UK HEIs, 66 stated that they offered some form of mathematics support provision. Interestingly, responses were obtained from all Russell Group institutions (19 HEIs), with 11 (58%) confirming that they offered some form of mathematics support provision.

This volume builds on the earlier body of work, this time examining the practicalities of mathematics support. It begins with papers provided by the keynote speakers. Professor

Celia Hoyles OBE, the then UK Government Chief Adviser for Mathematics opened the conference, speaking about the school-to-university interface and, in particular, activities that address issues surrounding the teaching of mathematics pre-university. Professor Tony Croft, Director of the Mathematics Education Centre at Loughborough University, and Professor Duncan Lawson, Director of the Mathematics Support Centre at Coventry University closed the conference with their joint keynote speech. Croft and Lawson, who are joint directors of **sigma**, the Centre of Excellence in University-Wide Mathematics and Statistics Support, spoke about the work of **sigma**, highlighting especially the dissemination of its activities.

The body of this volume contains papers submitted by the other speakers and is divided into four chapters. Chapter 1 explores different approaches towards delivering mathematics support, in particular the drop-in centre, appointment-based provision, the maths café, and various hybrids of these models. Chapter 2 reveals that mathematics support is not solely restricted to the STEM disciplines, but is also important for students in, for example, the social sciences. Chapter 3 addresses the institutional agendas mentioned above. Finally, Chapter 4 considers how mathematics support may be expanded into new areas and may utilise emerging technologies.

At the end of the first day, Dr Joe Kyle of the University of Birmingham chaired an illuminating panel session entitled *Affordability, Adaptability, Approachability, and Sustainability*. This session examined some of the key challenges faced by those involved in mathematics support, and in the epilogue Kyle discusses issues raised in this debate.

The conference was made possible thanks to the generous support of the Wilkinson Charitable Trust, the MSOR Network, and the University of St Andrews. These bodies, along with **sigma,** have continued their generous support enabling us to produce this volume.

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Mathematics and the Transition from School to University

C. Hoyles

In recent years there have been a number of Government-commissioned reports into mathematics education at all levels. These include:

- Early years and primary (Williams, 2008);
- Post-14 (Smith, 2004);
- University (Hawkes & Savage, 2000);
- Transition to workplace (Roberts, 2002), (Leitch, 2006).

Whilst the focus of these was concerned primarily with the situation in England, many of the observations made and lessons learned are applicable throughout the United Kingdom and further afield.

In this paper the focus is upon school mathematics and its implications for making the transition from school to university. The 2004 report of Professor Adrian Smith into post-14 mathematics was commissioned by the Rt. Hon Charles Clarke MP, the then Secretary of State for Education and Skills, following concerns raised within the Roberts report (Roberts, 2002) that looked at the future UK skills base. Smith's remit was:

> *"To make recommendations on changes to the curriculum, qualifications and pedagogy for those aged 14 and over in schools, colleges and Higher Education Institutions to enable those students to acquire the mathematical knowledge and skills necessary to meet the requirements of employers and of further and higher education."*

Smith raised concerns in three areas. These were:

- The failure of the existing curriculum and qualifications framework to meet both the mathematical requirements of learners and the needs and expectations of Higher Education and employers, as well as its failure to motivate students to engage in the further study of mathematics;
- The serious shortfall of specialist mathematics teachers in schools and colleges with the associated impact on the student learning experience;
- The lack of the necessary support infrastructure to provide continuing professional development and resources for those engaged in the delivery of mathematics provision.

Moreover, he concluded that:

> *"The Inquiry has therefore found it deeply disturbing that so many important stakeholders believe there to be a crisis in the teaching and learning of mathematics in England."*

Following on from Smith there is a need to ensure that necessary frameworks are put in place to enable young people to become confident and articulate in mathematics. This can be achieved not only by working with existing teachers to improve their knowledge and understanding of mathematics as well as pedagogies for its delivery, but also by encouraging inspirational new teachers into the profession. Indeed, a recent report by the Office for Standards in Education (Ofsted) into mathematics provision (Ofsted, 2006) observed that:

> *"The quality of teaching was the key factor influencing students' achievement…the best teaching gave a strong sense of the coherence of mathematical ideas; it focussed on understanding mathematical concepts and developed critical thinking and reasoning…in contrast, teaching which presented mathematics as a collection of arbitrary rules and provided a narrow range of learning activities did not motivate students and limited their achievement."*

Clearly, there is a need to address current concerns in the teaching of mathematics pre-university. However, we must face-up to the current situation and recognise that students making the transition from school to university and wishing to study quantitative subjects may not be adequately prepared. There is therefore a responsibility for universities to put in place appropriate support mechanisms to ease this transition phase.

Within these proceedings you will hear of the experiences of those currently engaged in addressing issues at the school-university interface. Authors discuss and explore various strategies and models for supporting those students who enter university with deficiencies in their mathematical knowledge.

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Enhancing the Quality of Mathematics Support throughout the UK: The Role of sigma

D. A. Lawson & A. C. Croft

Abstract

In 2005 **sigma**, a collaboration between Loughborough and Coventry Universities, was designated by the Higher Education Funding Council for England (HEFCE) as a Centre for Excellence in Teaching and Learning (CETL). **sigma** provides university-wide mathematics and statistics support at its two host institutions and a key feature of its philosophy is that mathematics support should be collaborative rather than competitive. This paper outlines the range of activities being undertaken by **sigma** and relates how **sigma** is working outside Coventry and Loughborough. It describes opportunities for interaction with **sigma**.

Introduction

The CETL initiative was HEFCE's largest ever single initiative in teaching and learning (HEFCE, 2007) with £315 million being allocated to fund CETLs. A two-stage bidding process took place. In the first round, over 250 submissions were received, each of which set out the case for excellence in a particular area of activity. Just over 100 of these submissions were then invited to submit a second proposal, which outlined how CETL funding would be used if the proposal were successful. Finally, 74 bidders were designated as Centres for Excellence.

Coventry and Loughborough Universities have well-established track records in the provision of university-wide mathematics and statistics support. In addition, they have a long history of collaborative working on external projects such as **math**centre (www.mathcentre.ac.uk) and **math**tutor (www.mathtutor.ac.uk). A collaborative bid from the Mathematics Learning Support Centre at Loughborough and the Mathematics Support Centre at Coventry was successfully submitted to the CETL programme and as a consequence, a new joint centre – **sigma** – was created.

sigma receives substantial funding from the CETL programme - £2.35 million over the first two years for capital expenditure (buildings, refurbishment and equipment) and £2.5 million over five years for recurrent expenditure (primarily staffing and day-to-day running costs).

In this paper we will outline the activities of **sigma** during the first two years of CETL funding, focusing not only on activity within Coventry and Loughborough but also describing work with the wider Higher Education community. The requirements of the CETL programme obliged each centre to allocate a comparatively small amount of its budget to external dissemination. From the outset, **sigma** wrote into its proposal a much larger figure than the minimum required. Details of external activities to date are given along with a description of opportunities for interaction with **sigma** in the future.

sigma Activities within Its Host Institutions

A comprehensive review and evaluation of **sigma**'s activities during its first two years of operation can be found in its Interim Evaluation Report (**sigma** 2007, available via www.sigma-cetl.ac.uk) submitted to HEFCE. What follows is a brief summary of some of the key features of this report.

Enhanced Drop-In Centres

The work of **sigma** is based on well-established mathematics drop-in centres at Loughborough and Coventry. Capital funding was used to refurbish and expand the drop-in provision at both institutions. As a consequence, usage of the drop-in centres has risen significantly. In the baseline year of 2004/5 (i.e. before **sigma**), the total number of recorded student visits to the drop-in centres at both universities was 6277 and by 2006/7 (the second year of **sigma**) the number of recorded visits had risen to 8166 (an increase of 30%).

Supplementary Teaching & Support

Drop-in centres are essentially reactive and require the student to take the initiative in visiting the centre. A new feature that has been introduced using CETL funding is proactive intervention where potentially "at risk" students are targeted and provided with additional or supplementary teaching. The value of this can be seen in feedback received from course tutors:

> *"Last year was the first year that nobody failed HUA405 (as far as anyone can remember this is a first!), so I think that is on its own evidence of the value of the support you provide."* Human Sciences, Loughborough University.
>
> *"I have just completed marking the 108DST exam scripts and calculated the final module marks … The results show a remarkable improvement on last year and I believe it is largely down to the maths support the students received in term 1."* Disaster Management, Coventry University.

Specialist Advice and Training in Statistics

A Statistics Advisory Service has been set up at both institutions to support students (both undergraduate and postgraduate) undertaking projects that require the collection and analysis of large amounts of data. This service operates by providing bookable appointments. The demand for these has been so great that at peak times they are fully booked for three weeks ahead or more.

In addition to working with individuals, a series of workshops covering a range of statistical techniques have been developed for research students and staff. These have been heavily subscribed and there is currently a substantial waiting list for future occurrences of the courses.

Specialist Support for Students with Disabilities

sigma has continued to support the work of the Dyslexia and Dyscalculia Interest Group (DDIG) that was already established at Loughborough. Specialist tutors have been employed to provide mathematics support to students with dyslexia and dyscalculia. The UK's first Postgraduate Certificate course relating to dyslexia and dyscalculia in mathematics has been developed and the first cohort enrolled in April 2007.

Existing expertise at Coventry with support for blind students has been further developed with support provided both internally and externally to a veteran American serviceman blinded during the Iraq war.

Investigation of Innovative Uses of Technology

A key element of the CETL programme was that bidders were encouraged to take risks in their proposals and suggest speculative activities. **sigma** has purchased a wide range of new ICT technology with a view to investigating its usefulness in improving mathematics and statistics support. A particular strand of this has been to look for ways in which technology that students are familiar with (such as MP4 players, mobile phones and social communication software) can be used to deliver mathematics support.

The **math**tutor video resources have been customised for use on video iPods and other MP4 devices and interactive materials are being developed for use on mobile phones. An embryonic mathematics group has been set up on the social networking site Facebook.

Materials have been developed and are being trialled for use with interactive whiteboards, personal response systems and tablet PCs. A series of "How to …" guides are being written and these are made available on **sigma**'s website.

Pedagogic Research

Many of **sigma**'s activities are practitioner-led. However, an important strand of **sigma**'s work has been to set up a programme of pedagogic research to underpin its developmental work. **sigma** employs a Senior Research Fellow at Coventry University and has contributed a newly created post of Professor of Mathematics Education at Loughborough University.

A cohort of PhD students has been recruited. These students are working in a range of areas including explicit evaluation of mathematics support approaches and investigations of the impact of new technologies on mathematics education in Higher Education.

sigma Activities in the Wider HE Community

A fundamental principle in **sigma**'s approach is that all the resources it develops and all its findings should be made freely available to the whole Higher Education community. To this end, **sigma** is working closely with the Maths, Stats and OR Network of the Higher Education Academy to disseminate resources, emerging practices and research findings. Two annual conferences, CETL-MSOR 1 and 2, have been held with over 100 delegates attending each conference (Green 2007, Green 2008). In addition, each edition of

Connections, the quarterly magazine of the MSOR Network, contains at least one article from **sigma** staff.

sigma contributed funding for two years to enable Leeds University to set up a mathematics support centre in October 2005. This centre has been so successful that the University has agreed to provide the funding required to keep it operational now that **sigma** funding has finished.

Following a competitive bidding process in 2007 that attracted applications from 14 universities, **sigma** has committed two years of funding to Bath and Sheffield Universities to enable the establishment of mathematics support provision at these two institutions. A condition of receiving **sigma** funding was that there must be matched funding from the host institution.

Staff from **sigma** have accepted invitations to lead professional development workshops and contribute to teaching and learning conferences at a large number of university and Higher Education Academy subject centre events.

A guiding principle in **sigma**'s operation is that mathematics support within Higher Education should be a collaborative not a competitive activity; a great deal of effort can be wasted in re-inventing resources that already exist. To reduce this potential drain on time and funding, all the resources that **sigma** develops are made available on its own web-site and/or the **math**centre web-site.

Opportunities for Future Interaction with sigma

sigma's interpretation of being a Centre for Excellence is that we are keen to work with anyone (from England, the UK or internationally) who can demonstrably contribute to the development of excellent practice. A number of staff from both home and overseas have already been seconded to work with **sigma** on specific projects and further secondment opportunities exist.

Broadly, **sigma** offers two kinds of secondment: long-term and short-term. A long-term secondment is the equivalent of 1 day per week for a semester and **sigma** will make a contribution to cover replacement teaching costs and travel expenses. In a short-term secondment, the seconded individual spends a week visiting **sigma** to observe our work in action. For short-term secondments, **sigma** covers the travel and subsistence costs of the seconded individual. For both types of secondment, the seconded individual must work on a project that is of benefit to both **sigma** and the seconded individual's home institution. At the end of the secondment, the seconded individual must produce a written report on the outcomes of the project.

In addition to secondments, **sigma** is happy to receive visits from staff working in or hoping to develop mathematics and statistics support in their own institutions. Visitors can observe our drop-in centres and other activities and engage in discussions with practitioners about the provision of drop-in support, statistics advisory services, supporting students with disabilities and using new technologies. Alternatively, staff from **sigma** are willing to contribute to workshops and seminars in other institutions.

Postscript

Whilst the proactive teaching interventions, identifying and targeting potentially "at risk" students, detailed in the section on Supplementary Teaching and Support above, worked well, not all the subsequent interventions were as successful. This was usually because the students failed to engage in the ways that we had intended. We have since learned a great deal about the importance of engaging students. For more information about the sigma interventions and lessons learned please see the **sigma** summer 2009 newsletter available via http://www.sigma-cetl.ac.uk/index.php?section=96.

In the section above covering **sigma** Activities in the Wider HE Community we refer to the number of CETL conferences as two. At the point of publishing, there have been four such conferences and a fifth is planned. Proceedings for the third and fourth conferences are available via http://mathstore.gla.ac.uk/index.php?pid=61.

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CHAPTER ONE

Flexible Delivery: Models of Support

The Drop-In Centre Model of Mathematics Support

D. A. Lawson

Abstract

In order to address the well-documented problem of the changing nature of mathematical skills possessed by new undergraduates, many universities have introduced some kind of mathematics support provision. A number of different models of mathematics support can be found throughout the UK. This paper focuses on one model: the drop-in centre. Coventry University is used as an exemplar of this approach. The advantages of a drop-in centre are considered along with a discussion about some of the issues that must be addressed when establishing and running a drop-in mathematics support centre.

Introduction

A series of reports by professional bodies, learned societies and the British Government (for example, Sutherland and Pozzi (1995), LMS et al. (1995), Hawkes and Savage (2000), Smith (2004)) have highlighted problems in pre-university mathematics education. In the report of the National Inquiry into Post-14 Mathematics Education, Smith (2004, p. v) says:

> *"The Inquiry has found it deeply disturbing that so many important stakeholders believe there to be a crisis in the teaching and learning of mathematics in England."*

In addition to changes in pre-university education, universities have also had to cope with a changing pattern of demand for courses. Sutherland and Pozzi (1995, p. 6) report that:

> *"The reduced popularity of mathematics and science A-levels, together with the increasing proportion of school leavers entering university, has put pressure on a number of engineering departments to accept students with lower entrance qualifications than they would have done 10 years ago."*

It is a commonly held perception amongst academic staff that new undergraduates do not possess the same level of mathematical skills as their counterparts from 10, 15 or 20 years ago. Indeed, Sutherland and Pozzi (1995, p6) state that:

> *"Just over half (55%) of lecturers surveyed said that the mathematical background of their engineering students is undermining the quality of their engineering degrees."*

The need for mathematics support is based upon the axiom that new undergraduates are often mathematically unprepared for their course of study in Higher Education. Undoubtedly many current staff would support the following statement:

> *"Many students of science subjects arrive at university with little facility and less interest in mathematics."*

However, the above statement was made in a paper published in 1973 (Baker et al., 1973). It is even rumoured that Pythagoras complained about the quality of his students! Before investing heavily in mathematics support it is essential to determine if it is really needed or if it is based on academic staff viewing the past through rose-coloured spectacles.

In a number of institutions, data has been gathered from diagnostic testing. At Coventry University the same 50-question diagnostic test has been used since 1991. This test contains questions covering seven areas: arithmetic, basic algebra, lines & curves, triangles, further algebra, trigonometry and basic calculus. The questions are designed to test students' fluency in, and grasp of, basic mathematical techniques. Outcomes from the test have been reported elsewhere (Hunt & Lawson (1996), Hunt & Lawson (1997), Lawson (2003)) and this information will not be repeated in detail here. A single graph will be used to illustrate the nature of the change in new undergraduates' mathematical skills.

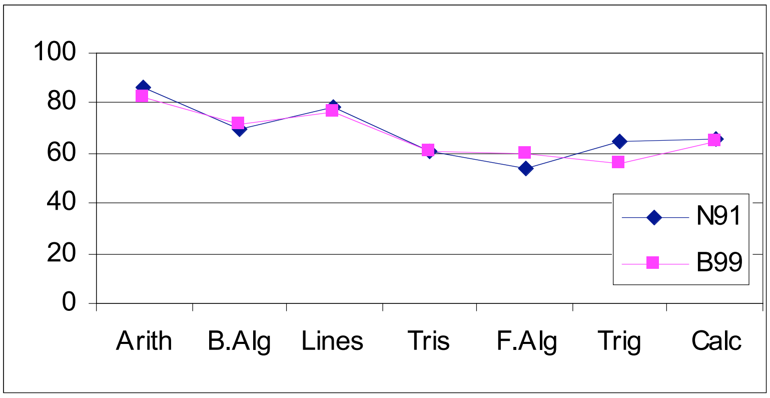

Figure 1. Diagnostic test results of 1991 Grade N and 1999 Grade B students

Figure 1 shows the results of two cohorts of students who took the diagnostic test in 1991 and 1999. There is very little difference between the results of the two cohorts. However, the cohort from 1991 consisted of all the students who had achieved A-Level Mathematics grade N (i.e. a fail grade) and the cohort from 1999 consisted of all the students who had achieved A-Level Mathematics grade B (i.e. the second highest grade possible). This illustrates the dramatic change in basic mathematical skills amongst new undergraduates over the decade.

In many ways, the position regarding A-Level Mathematics is only the tip of the iceberg. Many students are admitted to courses with a quantitative element (Economics, Business Studies, Biology, Psychology, etc.) with only GCSE Mathematics grade C and no study of mathematics post-16. The amount of mathematics mastered by a student achieving GCSE grade C is not large (a mark of around 20% is all that is needed (Clark, 2004)).

As a consequence, many students in Higher Education are inadequately prepared for the quantitative elements of their courses. It is to assist such students that many universities have introduced some kind of mathematics support provision.

Mathematics Support at Coventry University

Formal mathematics support was introduced at Coventry University in 1991. Prior to this an informal mathematics workshop had operated a few lunch-times each week. In 1991, funding was secured from the BP Engineering Education Fund for the establishment of an extensive mathematics support provision for Engineering students.

The BP Mathematics Centre was based on two key principles:

- The early identification of problems;
- The provision of on-going support.

The *early identification* of problems was achieved through the use of widespread diagnostic testing. Initially diagnostic testing was only used with students on "at risk" courses. Typically these were Engineering HND courses (where most students had passed only one A-Level (or equivalent), usually not mathematics) and Engineering degree courses with lower level mathematics requirements (such as production and manufacturing). However, as time passed, the range of courses deemed to be "at risk" continued to grow and now the overwhelming majority of students on courses with a quantitative element take one of a range of diagnostic tests during their induction week at the university.

The *provision of on-going support* was achieved through the opening of a drop-in support centre. The BP Mathematics Centre was staffed for 30 hours per week and during this time students could come for a one-to-one consultation with the duty member of staff. No appointments were made – the students simply "dropped in".

In view of the source of the funding for the Centre, its initial focus was on Engineering students. However, when the funding from BP finished and as other parts of the University recognised the value of the service being provided, the Centre changed its name to the Mathematics Support Centre and its remit expanded in the first instance to any student taking a Mathematics or Statistics module and then to any student in the University.

The one-to-one support has remained at the heart of the mathematics support provision. However, this has been supplemented by the development of an extensive range of paper-based and electronic resources that are freely available via the Centre's web-site at https://cuportal.coventry.ac.uk/C13/MSC/default.aspx. The Centre has also been involved in collaborative projects to develop resources available to the whole HE community, notably **math**centre (see www.mathcentre.ac.uk) and **math**tutor (see www.mathtutor.ac.uk).

The Centre is now viewed as a key University resource in supporting students (Coventry University, 2006) and in 2005, in collaboration with the Mathematics Learning Support Centre at Loughborough University, it was designated by HEFCE as a Centre for Excellence in Teaching and Learning (CETL).

The Advantages of a Drop-in Centre Model

The mathematics support provided by drop-in centres is usually in addition to the "normal" teaching that students receive. Providing support in this way has a number of advantages, in particular:

- The use of a drop-in model puts the service very much into the students' control. They come at times that are convenient to them and as often as they wish;
- By having a fixed location, it is possible to make available a range of resources that students can use either when they are waiting to speak to staff or instead of consulting with staff;
- The centre is not involved in the assessment process so it is demonstrably "on the student's side";
- Because the centre is dealing with students from across the entire university, nothing is too basic to be asked. No judgements are made that "you should already know this". This is crucial as a fundamental part of the centre's role with many students is building their confidence that they can achieve in mathematics despite their previous experiences;
- A busy drop-in centre can become a place that fosters interaction between students and hence promotes peer support.

When the Coventry Centre was originally conceived, the model was very much one of being a service for "weaker" students. In this context, "weaker" did not necessarily refer to ability but preparedness: the Centre has dealt with some very able students – often mature students – whose educational background, particularly in mathematics, has been less than ideal for the course of study they are undertaking in HE. Whilst such students remain a key constituency in the work of the drop-in centre, there has been a clearly identifiable trend over recent years whereby more able students have seen the Centre as a valuable learning resource. Such students often use the Centre in groups – primarily working together and drawing on the non-staff resources available in the Centre and only occasionally referring to the duty staff.

Discussion

When establishing a mathematics support centre there are some key issues that need to be faced. One of these is the issue of location. There are two principal options:

- Close to or within the mathematics department;
- Within a central academic support unit.

There are advantages and disadvantages of either approach. Locating a centre within a mathematics department can be advantageous where that department is responsible for the service teaching throughout the university. In these circumstances, the centre can retain academic credibility more easily and also, hopefully, use mathematics department staff to provide both a range and depth of expertise, thereby enabling the centre to offer a broad range of support. However, there are disadvantages in this location too: students who are lacking in confidence mathematically may be less willing to visit a centre in the mathematics department. Moreover, if the centre uses staff from the mathematics department then the separation from the assessment process may be perceived to be less than total.

If the centre is located within a central academic support unit, this can have the advantage of being completely divorced from the "normal" teaching and assessment. It can also mean that students may visit the support unit for a different kind of support (for example, study skills) and then come for mathematics support because it is available there without them having to make a separate journey to a different location. However, typically when mathematics support is located in a central unit, the level of mathematics that is routinely supported is much lower. It can also be more difficult to secure the support of the mathematics department staff which can be crucial both in terms of delivering the support and of promoting it to students.

The most fundamental issue that must be addressed regarding mathematics support is funding. Provision of a drop-in centre such as the one at Coventry University, which is staffed for 30 hours per week, is costly. Someone has to pay for this service. On the one hand, the financial arguments are strong: the loss of fee income from 10 first year students who drop out of their course because they cannot cope with its mathematical components more than covers the cost of providing the service. However, it is difficult to establish incontrovertibly that 10 students a year have been retained who would have been lost if the centre did not exist. Furthermore, even if this is accepted there is still the case of who should provide the funding. The 10 retained students are unlikely to be evenly spread across the university – the centre will be perceived by Arts and Humanities faculties as providing more benefit to Engineering and Sciences faculties than to themselves. There is no easy solution to this problem and it is often decided by internal politics rather than by logical reasoning.

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The Portsmouth University Maths Café: Making a Virtue of Necessity

L. Pevy

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Abstract

This paper describes the Maths Café, the mathematics support facility that operates at the University of Portsmouth. The Maths Café operates primarily in café locations across the campus using wireless laptops and resources that can reasonably be transported around the campus in a Maths Café trolley. The Maths Café is organised and controlled by a team within the Mathematics department, and most members of staff in the Mathematics department are involved to some extent with the operation of the scheme. It is a high profile drop-in/stop-off model that integrates its publicity with its day-to-day operations.

This paper explains how the constraints and opportunities at Portsmouth led to the development of the Maths Café model. The paper examines the advantages and disadvantages of those features that distinguish the Maths Café from other mathematics support facilities. It explains how some of the positive aspects of the operation of the Maths Café arose from a necessity to develop the scheme within tight financial constraints.

Introduction

The Maths Café at Portsmouth, an innovative scheme for delivering university-wide mathematics support to all members of our academic community, was launched in 2002 although preliminary discussions, formulation of plans, funding negotiations, and pilot trials had started many months previously. The Mathematics Department oversees the Maths Café, and the model developed distributes the responsibility for its day-to-day operation amongst all academic staff in the department. In addition, a team of five shares responsibility for other aspects of the management of the Maths Café such as publicity, maintaining and developing resources, production of an annual report, diagnostic testing, additional seminars, and forward planning. The Maths Café was formally launched at the official opening of our new Student Union building and since then has been operating successfully, maintaining the key aspects of its original format whilst augmenting it with further provision.

In common with staff at many other HE providers we had been observing first hand the increasing difficulties caused by the mismatch between the quantitative skills of our intake and the expectations of their lecturers. For staff in the Mathematics Department this quantitative skills gap was most obvious in the large tutorial classes for courses in Engineering. These cohorts of students covered a wide range of abilities and mathematical backgrounds. The range in mathematical experience was not merely a consequence of changes in mathematics syllabi in the United Kingdom: the prior experience of many of our international students entering undergraduate courses at Level Two resulted in strong algebraic skills but a lack of experience with graphs. Inevitably, tutorials with such large mixed cohorts of students would leave some students bored while well-known material was revised or would leave others bemused if that knowledge was assumed. The situation was becoming unmanageable, and it was recognised that some additional facility was required to underpin the Mathematics Department's service teaching.

The development of a mathematics support centre was seen as the most appropriate way to address the needs of those students who continued to study mathematics at University but who needed additional support. The Mathematics Support Centre at Loughborough University was often cited as a model of good practice and one that Portsmouth should emulate, and the proposal to establish such a facility was mooted on a number of occasions. However, even those in support of the principle baulked when considering the size of the investment required.

The impact of the quantitative skills gap for those students studying mathematics within their course was felt long before the impact of the changes in GCSE syllabi on those students not requiring a high level of mathematics was recognised. The problem with the revised GCSE syllabi was that students entering with a grade 'C' might never have encountered some of the mathematics that their lecturers assumed, based on prior experience, to be "common knowledge". The University already provided support in basic numeracy through its Academic Skills Unit, but there was a growing need for support for students requiring specific gaps in their mathematical knowledge to be filled in order to understand lectures in their other subjects.

In March 2001 an internal Mathematics Department paper (by the author) proposed the setting up of a Mathematics Workshop. The mode of operation initially proposed was not significantly different to that operating at other institutions. One major difference at this stage was the inclusion in the proposal of an underlying principle: in order to reach its maximum potential all staff in the Mathematics Department would be involved. This would also reduce the costs as all Mathematics lecturers already had designated hours when their own students could come and talk with them, and this was integrated into the Mathematics Workshop proposal. The proposal, including the principle of an equitable sharing of work, was supported by the Department, and the costs of the proposed scheme were calculated. The proposal was welcomed by the Faculty and the appropriate member of the University Directorate, and there was general acceptance, among all involved in the discussions, that the scheme would probably soon pay for itself in terms of student retention. Unfortunately, since it was impossible to identify the extent to which individual departments or faculties would benefit financially by the retention of their students, no agreement was reached on the financing of the scheme. Consequently, with no funding source, the Mathematics Department did not proceed with the proposal.

From August 2001 references to the 'Curriculum 2000' problem began appearing in the national press. An article by Nicholson and Belsom in the June 2002 issue of Mathematics Today summarised the statistics and the issues. Their reported figure of a 28.6% failure rate for AS-Level Mathematics was alarming: there was a growing concern that many students would not continue with Mathematics after disappointing AS-Level results, and departments that traditionally expected the majority of their students to have taken Mathematics at A-Level would find themselves having to admit increasing numbers with poorer and less recent qualifications.

Despite the lack of financial support for the Mathematics Centre proposal, two members of the Mathematics Department decided to proceed with the scheme, albeit with a minimal service, recognising that it was most likely to be accepted based on proof of concept. This amounted to no more than booking a room for a few hours a week and advertising the facility to those groups of students taught by the Department. The initiative was much valued by the very few students who discovered it and lessons learnt from the experience informed the future development of the Maths Café. The out-of-the-way location, unfriendly operating hours, and reliance upon face-to-face advertising were identified as the features most likely to have deterred students from utilising the resource: it was observed that in order to encourage future students to take the initial step towards seeking help, high visibility and good advertising must be prioritised.

The Maths Café

In the summer of 2002 the construction of a new Student Union building was nearing completion and the Student Union had ambitions that this new facility would contribute in some way to the academic life of Portsmouth University students. It was suggested that, instead of having a Mathematics Centre within the Mathematics Department, we could offer support informally in the entertainment area of this new building, thus providing it with a daytime function. The Faculty of Technology agreed to fund the purchase of a laptop as well as the necessary advertising if the Mathematics Department agreed to this. A small group toured the partially completed building, rejected the very noisy area initially proposed, but agreed to the café area subject to sufficient publicity and visibility. The name “Maths Café” was settled upon immediately. The Maths Café team was established and, keeping visibility and approachability as high priorities, the Maths Café was launched a month later on the day the building was officially opened.

Figure 1. The Maths Café in operation.

It was agreed that the Maths Café would operate for four hours a day in the Student Union Café, two hours at lunchtime and two in the late afternoon. Good publicity was an essential component, and the Maths Café took the Student Union colours of purple and orange for all its publicity. Two members of the Maths Café worked with the Marketing Department to produce some garish, yet effective, posters and signs ready for the launch. Although working with the Student Union had not been part of initial plans, the significant advantages of operating on their premises – for instance free advertising in Student Union publicity materials – were immediately apparent.

Part of the original Mathematics Support Centre concept was that, in order to cope with simultaneous questions and support further learning, students would be directed to Computer-Aided Learning (CAL) packages. However, since the Maths Café had only one laptop, CAL resources could be demonstrated but could not be provided for student use. To overcome this, each day, between the two café sessions, the Maths Café was set up in a computer laboratory.

The main intention of the Maths Café was to address issues surrounding the quantitative skills gap on undergraduate courses. It was envisaged that the facility would effectively pay for itself through the retention of students who might otherwise have abandoned their studies. From the outset it was important to the Maths Café team that there was no stigma attached to using the facility and that it was an entirely positive experience for the students. Therefore the Maths Café was never intended solely as a support mechanism for failing students but as a facility to be used by any student (or member of staff) wishing to improve their mathematical and statistical skills. This was reflected in all publicity material. Moreover, the team adhered to the original intention that all staff in the Mathematics Department would be involved, thereby ensuring that all queries could be addressed; obviously some staff are more effective and/or enthusiastic than others, so not all staff are given identical responsibilities. However the principle remains that all are expected to provide help when requested.

The Maths Café proved to be successful both in its support of students and in its ability to publicise itself. Departments in which there is no teaching of mathematics but where some mathematical competence is essential were particularly ill equipped to deal with the quantitative skills gap. The recognition that the Maths Café could effectively solve this problem led to its inclusion in a wide variety of University documents, particularly Quality Assurance documentation such as course review, course validation, and programme specification documents. It is this recognition that was instrumental in changing the scheme from a shoestring project into a properly funded operation. The Maths Café now has a well equipped Base Room within the Faculty of Technology and is in receipt of adequate financial support from central funds to cover both staffing and capital expenditure.

Observations

In many respects the service provided by the Maths Café differs little from that provided by many other learning support schemes: the importance of individual support for struggling students, complemented by additional resources, is key. No attempt has been made to create additional resources – those developed elsewhere are used alongside some already in existence locally – and all time and energy is dedicated to providing mathematical support and encouraging the use of the facility.

Where the Maths Café differs from most other learning support providers is the way that locations are used to integrate the support with the advertising. Although most Maths Café staff would themselves prefer to work in quiet environments, since one of the concerns of learning support providers is getting the students most in need of help to make the initial move, highly visible and easily accessible locations have been chosen in preference. The difficulty of "getting them through the door" is overcome by the Maths Café by effectively removing the door. Traffic at the Base Room has steadily increased and now accounts for just over 50% of visits, however many of these students will have made initial contact via a café location even if this contact is simply to establish whether the Maths Café might be able to help them with problems they anticipate in the future.

In the first year of operation 198 visits to the Maths Café were recorded. The number of visits continues to rise and reached 646 in 2006-2007.

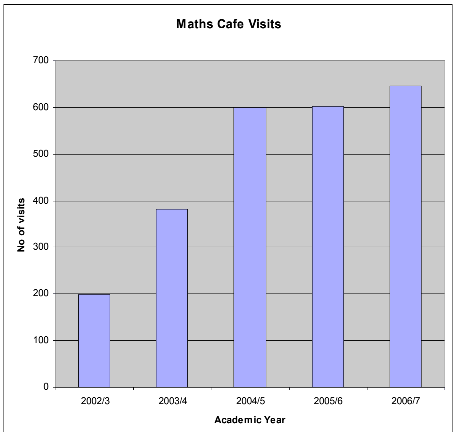

Figure 2. Visits to the Maths Café, 2002-7.

The fact that the Maths Café is now well established and that the use of support in café locations has decreased overall might seem to imply that it is time to stop operating in some of the noisier café locations. There are, however, no plans for this to happen as the team considers that this would be detrimental to the Maths Café publicity and locations used are reviewed annually in response to requests from other departments and changes in the University estates.

The Maths Café team has long recognised that most students expect to spend three years at University. For any individual student there is a three-year window for them to discover and use the facility, however, those who discover shortcomings in their mathematical skills are most at risk of withdrawing from their course at an early stage. It is the team's intention to keep the facility easy for students to find out about, easy for them to find, and easy for them to approach. The team is particularly active in Freshers' week, providing introductory talks when requested by other departments and, more importantly, attending the Freshers' Fayre, entering the flow of traffic and trying to make a friendly first approach to as many students as possible.

Conclusion

In terms of making a virtue out of necessity…the Maths Café model was introduced because the funding necessary for a more conventional Mathematics Support Centre could not be raised. The format was developed in order to achieve a number of agreed priorities within a set of tight financial and space constraints. Following the success of the Maths Café, the University now has a Mathematics Support Centre, however in the interim period the Maths Café brand has become so well established that the Mathematics Support Centre has been renamed the Maths Café Base Room. The Maths Café team made such a virtue out of a necessity that, even though finances now permit the change in the mode of operation, they have no intention of abandoning those practices that have brought about such positive benefits. In particular they value the high visibility and obvious accessibility of the café operations and the Maths Café will retain its café presence.

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The University of St Andrews Mathematics Support Centre: An Appointment-Based Model

C. M. Marr

Abstract

This paper discusses the founding and subsequent development of the University of St Andrews Mathematics Support Centre, a place where students from across all subjects and at all levels can get one-to-one tuition on any mathematics-based problem. It explores in particular three key features of the Centre: the appointment-based model; its physical and organisational location within the University; and the strategic use of attendance patterns. The paper reflects on observations made since the founding of the Centre, before concluding by looking to the future and proposing ideas for sustainability.

Background

Founded in 1413, the University of St Andrews is the oldest university in Scotland and, after Oxford and Cambridge, is the third oldest in the UK. It is a relatively small university with just under 6000 undergraduates and fractionally over 1000 graduates. The majority of University buildings lie within the heart of St Andrews, a small historic town in Fife on the east coast of Scotland. St Andrews is a highly academic institution that is renowned both for its research excellence and for its quality of teaching: the University was ranked 3rd in *The Guardian* newspaper's UK Good University Guide 2010. It is greatly over-subscribed: average undergraduate entry grades are 28 points at A Level (equivalent to AAB) and 26 points in Scottish Highers (equivalent to AAABB).

There is a widespread misconception that mathematics support centres provide only remedial help to failing students. At St Andrews we observe that this is far from the case: the majority of students attending the Centre are highly motivated and we see as many students aiming to get top firsts as we do students aiming simply to achieve sufficient points to pass. In addition, we see a significant number of students wanting help with numerical reasoning tests in preparation for graduating and applying for jobs.

Founding of the Mathematics Support Centre

St Andrews University Mathematics Support Centre opened in May 2005, run by a single member of staff working on a part-time basis. It became part of SALTIRE, the University's learning and teaching unit, which, as well as being responsible for academic audit, e-Learning and WebCT (the University's virtual learning environment), already had a Learning Support Consultant whose remit includes helping students with their studies, scheduling and presentational skills, academic referencing, and with avoiding academic misconduct.

The founding of the Mathematics Support Centre came about as the result of the convergence of a number of factors. First, the University had for some time been aware of concerns amongst staff about the broad range in the quantitative skills of its students. This was particularly noticeable in subjects with significant mathematical content but where entry requirements did not insist on the student studying mathematics post-sixteen. Staff from these disciplines observed that some students found the pace of the more mathematical


Figure 1: A typical one-to-one tutorial

topics too rushed while others found it frustratingly slow. Moreover, if a student failed to grasp a particular concept requiring quantitative skills, the hierarchical nature of mathematics meant that they would struggle with subsequent lectures on that topic.

At the same time, the (now) Head of the Mathematics Support Centre, a person with a strong academic profile but also with experience teaching mathematics both at secondary and tertiary levels, arrived in St Andrews, for personal reasons, seeking a job. Having visited and been inspired by the Mathematics Support Centres at Loughborough and Coventry, she proposed the idea of such a centre to St Andrews. With the University aware of anxieties, both nationally and amongst its own staff, about the quantitative skills of students, but not having identified a cost-effective solution, the idea fell on fertile soil.

The Model: Its Advantages and Disadvantages

Both the timing of its opening (just as the long vacation started, resulting in only a few students, post-graduates and those doing re-sit examinations, requiring assistance for the first couple of months), and its location within SALTIRE (and the resultant influence of pre-existing structures) played major parts in determining the model adopted by the newly founded Mathematics Support Centre.

An Appointment-Based System

With the exception of a few small group courses run throughout the year, most students requiring help from SALTIRE's Learning Support Consultant, are seen by appointment on a one-to-one basis. This, coupled with the relatively few students requiring help during that first summer vacation, meant that an appointment-based system was the natural choice for the St Andrews Mathematics Support Centre. Appointments are one-to-one and typically last one hour (45 minutes at peak times of the year), and students come with focussed questions that have arisen from their studies.

The appointment-based model is very different from the drop-in model adopted by most other mathematics support centres across the UK (although increasingly, centres are beginning to run appointment-based tutorials in conjunction with their drop-in sessions). There are advantages and disadvantages of each model. In the drop-in model students can effectively set up their own study groups whereby clusters of them taking the same course regularly congregate and work through tutorial sheets together, ironing out queries both amongst themselves and with the help of staff working in the Centre. For these models, a measure of success is the number of repeat visits by each student.

By way of contrast, a measure of success for the appointment-based model is how quickly the tutor is able to “clear” the problem encountered by the student: this corresponds to a low average number of visits per student, at least in a given time period. Thus, tutorial sessions are carefully tailored to, and dictated by, the precise needs of the individual student. For students who have failed to grasp a concept, through carefully chosen questions, the tutor can take time to identify the root of the problem, ensure that the student overcomes that hurdle, and then go on to build in further complexity to prepare them for subsequent lectures. For students who wish to take their studies beyond the confines of the syllabus, staff in the Centre can given them pointers to further reading and help them understand new and unfamiliar topics and techniques. Surprisingly, records over the first two years have indicated that, on average (and with a very long tail!), we are able to clear problems within one or two sessions demonstrating that the one-to-one model is, in fact, both cost-effective and time-efficient.

There are three final observations to make about the appointment-based model. First, it requires a level of maturity and organisation on the part of the student: in order to make the most out of a session, the student needs to have focussed questions and be clear about what areas they would like help with. Second, this model means that staff working in the Centre can manage their time effectively as they know precisely when they are teaching and when they have time to catch up on administrative duties. Interestingly, it also helps students to manage their time effectively as they do not have to queue. Finally, this model is highly conducive for members of staff who work part-time and who wish to work flexible hours: provided that diaries are kept up to date so that administrative staff know which slots are available to students, it is perfectly easy to work on different days each week.

Physical and Organisational Location of the Unit

The physical location of the Mathematics Support Centre – in an attractive old building in the centre of town and close to the library – means that it is both inviting and easily accessible. Students regularly drop by to make appointments as they are passing, with many squeezing in sessions at the Centre in between lectures. Moreover, the fact that the Centre is neither attached nor affiliated to any of the academic Schools makes the experience of visiting the Centre for the first time a less stressful one for the maths-phobic students amongst us.

We have already observed that the Mathematics Support Centre was set up as part of SALTIRE, the University’s learning support unit. As such, within our model, all sessions are delivered internally rather than by staff seconded from academic Schools. This has both advantages and potential disadvantages. On the plus side, the fact that sessions are given by someone who neither delivers their lectures, takes their tutorials, or indeed assigns their grades, means that students gain a fresh perspective on the material. Furthermore, they feel able to ask those “silly” questions, often key stumbling blocks, which they have been too embarrassed to ask in front of their lecturers, tutors, or peers.

A potentially negative by-product of being housed within the learning support unit and delivering all tutorials internally is that staff working in the Centre have to be confident about handling questions both from a wide range of topics, covering pure maths, applied maths, and statistics, and from an even wider range of application domains. Moreover they have to be aware of, and sensitive to, the different approaches that different Schools have to similar topics: for instance, when teaching statistical analysis techniques some Schools focus on the theory behind the technique, others focus on the "number crunching" and interpretation of results, whilst the remainder focus on the circumstances under which it is and is not appropriate to apply the technique.

The Strategic Use of Attendance Patterns

At the end of each academic year, the Head of the Mathematics Support Centre prepares a summary report outlining attendance patterns for that year (ensuring that information given cannot be used to identify individual students). In addition, reports are prepared on a School-by-School basis, summarising numbers visiting the Centre by year group or by module, and identifying topics for which they have been seeking assistance. These reports are given to the Vice-Principal (Learning and Teaching) as well as to the relevant Directors of Teaching and Heads of School. Obviously, this information is potentially sensitive, and it is up to the recipients to respond if they require clarification or wish to mine further.

An example of the highly effective use of one such report has resulted in collaboration with the Physics Department, leading to improved student learning and more effective use of staff time. The Director of Teaching for Physics contacted the Mathematics Support Centre following the first annual report. The report in question confirmed concerns within the School that their students' failure to recall, and hence apply, mathematical techniques and properties learnt in the first year was leading to a failure to understand physical concepts taught in the second year. Together we devised a series of five compulsory lectures to be delivered, jointly, by the Physics Department and the Mathematics Support Centre, at the beginning of the second year. These lectures cover all the mathematics that the students are meant to know and upon which they will rely in their studies that year. Moreover, all students are required to take a test on this material a few weeks later. Failure to clear this hurdle, which has a high pass mark but no tricks or traps, and which can, if necessary, be repeated a number of times, would result in the student not being allowed to continue their studies. It should be noted that for the two years that these lectures have been delivered, no student has had their studies terminated, staff have observed improved understanding in lectures and tutorials, and subsequent visits to the Mathematics Support Centre by this cohort of students have been all but eliminated.

Observations

Since its inception in 2005, the St Andrews University Mathematics Support Centre has become a highly successful part of the learning support unit. From the start, it has been working to full capacity with over 350 student visits per year by students from a wide range of disciplines (15 out of the 18 academic Schools) and from across all year groups.

Advertising and promotion of the Centre amongst the student body, or at least those taking modules with a mathematical component, has been key from the start. Leaflets are handed out at Matriculation at the beginning of the academic year, but the most effective form of promotion has been targeting specific cohorts of students, going into their lectures, and reminding them about the service. Endorsement by Schools (such as promoting the Centre in departmental handbooks) has also had a significant impact on attendance.

Two unanticipated, but positive, features of the Centre have emerged. The first, discussed above, is the way that Schools can use attendance patterns at the Centre to improve the student learning experience and encourage students to take responsibility for their own learning. The second is the number of students, typically from the arts subjects and in their final year, who have taken advantage of the Centre to help them prepare for numerical reasoning tests either for acceptance for further studies or for future employment.

A key factor in the effective running of the Centre is efficient diary management by SALTIRE's excellent administrative staff: high contact time means that it would be almost impossible for those delivering tutorials to manage their own diaries. When taking bookings, administrative staff take details such as the module with which the student requires help, as well as trying to extract from the student a more detailed description of the nature of their query: knowing in advance roughly what to expect removes a great deal of stress from the job.

A final observation is that the increased numbers of both staff and post-graduate visits to the Mathematics Support Centre indicates its increased academic credibility within the institution: the potential for a lack of academic credibility for such a centre is, perhaps, a negative side effect, not observed above, of locating such a unit within learning support rather than an academic School.

Efficacy, Efficiency and Sustainability: Looking to the Future

The Mathematics Support Centre has developed and grown since its inception in May 2005. In the first year, the overriding goal was "proof of concept": verifying the demand for such a service and refining the model to improve efficiency and effectiveness. As observed above, it became apparent from an early stage that it was impractical for tutors to manage their own diaries. Moreover, as administrative staff became more familiar with the names of mathematical concepts, diary entries became more informative enabling the tutor to be better prepared. Most recently, administrative staff have begun sending out reminders the day before the appointment, leading to a significant reduction in the number of "no-shows" and late cancellations. Thus, where students cannot make the allotted time, and exploiting the prevalence of mobile phones, slots are generally filled with other students waiting for appointments. This increased efficiency has resulted in a reduction in waiting times.

Having established the "proof of concept", the goal for the second year was to consider sustainability. Collaborations such as that with Physics mentioned above were very effective: three hours lecturing at the beginning of the year, and a couple of tutorials with the very few students who failed to pass the test first time, has led to an almost complete eradication of visits from that cohort of students for the rest of the year. More recently, and based on attendance patterns for the previous two years, where significant numbers of students are seeking help with similar topics in the run up to a class test, we have been running small group tutorials. Early signs indicate that this is an effective strategy: whilst moving away from the one-to-one tuition with which the Centre is most associated, for these carefully selected topics the fresh perspective seems to be having the desired effect – although we have learnt that, in future, we must allow longer to cover the same amount of material in a small group tutorial than we would in a one-to-one session.

In 2007 there were two overriding goals. The first, following on from a survey that indicated that whilst the student body is making effective use of the Centre, many staff are unaware of the service, was to promote the Mathematics Support Centre amongst staff: this is important so that staff can, in turn, recommend the Centre to their students. Thus far, this goal has been only partially achieved: the Head of the Mathematics Support Centre gave a talk about the service to all Library staff, and, with the Learning Support Officer, has regular lunchtime meetings with staff from Student Support Services. There has, however, been less success in reaching out to the academic staff. Whilst presentations have been given to Heads of Schools and Directors of Teaching, requests to give presentations at departmental meetings have been largely ignored: agendas for such meetings are generally very full and it is hoped that with a little time and perseverance this goal will ultimately be achieved.

The second goal was a slightly different take on the previous years' goal of tackling sustainability, given that student demand for mathematics support is ever increasing. Rather than aiming to decrease demand by running group sessions, we have been exploring how best to increase the service in a cost-effective manner through the employment of additional graduate tutors. The graduate tutors have a reduced remit: they see neither staff nor other graduate students, and are allocated (as much as the administrative staff can predict in advance) only students wanting help with a subset of topics corresponding to their skill base. Although entirely dependent upon the calibre of the graduate tutor, this trial appears to be very positive. In particular, students requiring repeated assistance (for instance those recommended by Student Support Services) can be seen by the graduate tutors freeing up more time for the Head of the Centre to see those with more complex demands. We have learned that the most important factor is that the level of service is retained, that the Centre doesn't become a victim of its own success due to the relative inexperience of the graduate tutors. Thus far, things bode well and we plan to continue with this expanded service next year.

Mathematics Support: Looking to the Future

E. Meenan

Abstract

This paper outlines the history that led to the establishment of a Mathematics Support Centre at the University of Leeds and describes the service that the Centre provides. It explores the needs of specific cohorts of students and how these needs are addressed. Findings are complemented by feedback from individual students. The paper concludes with the observation that the recruitment of tutors with experience from outside the university environment can give added value.

Introduction

In early 2005, the Mathematics Education Centre at Loughborough University and the Mathematics Support Centre at Coventry University were jointly awarded CETL status by HEFCE. The CETL, known as **sigma**, is concerned with university-wide provision of mathematics and statistics support and one of its main objectives is to share good practice and develop partnerships and collaborations with other universities. As such, the University of Leeds became a "dissemination partner" and funding provided by **sigma** enabled the University to establish a Mathematics Support Centre in July of that year. The Centre is housed within the University's Skills Centre and a part-time Mathematics Support Tutor, working two days per week, was appointed initially for two years.

Liz Meenan, the Tutor appointed, has an interesting and varied background: she had previously been Head of Mathematics at a secondary school, an advisory teacher for Leeds Local Education Authority and an Education Officer at Channel 4. She continues to be a freelance mathematics consultant to schools, Local Education Authorities and organisations such as Channel 4 and the BBC. It was felt that she had the qualities and wide-ranging experience to help support students and work with University staff to set up the Mathematics Support Service/Centre in the Skills Centre.

From September 2005 the newly founded Mathematics Support Centre offered mathematics support to any student in the University but in particular to those students making the transition from school/college to university. To provide this support one of the rooms in the Skills Centre was used for maths drop-in support. This room has three networked PCs for student use, with **math**tutor/**math**centre resources (in both paper and electronic formats) as well as other mathematics resources and books available both for loan and for student use in the Centre.

Promoting the Centre, not only to relevant cohorts of students but also to colleagues within the Skills Centre, was an early priority and the Mathematics Support Tutor achieved this in various ways:

- Presenting a workshop at the Skills Centre on the service and support that the Centre would offer to both staff and students;

- Delivering short talks in departmental lectures to first year Chemistry, Physics and Mechanical Engineering students;
- Taking advantage of the Skills Centre website and its promotional leaflets.

Drop–Ins

A key element of the Mathematics Support Tutor's role is to organise, facilitate and deliver drop-in sessions to provide help to students with specific mathematics problems. These sessions are free, confidential and are for students of all disciplines. There is no need to book an appointment in advance. Sessions are run four days per week, with each session lasting two hours, and are held in the drop-in room at the Skills Centre. On days that the Mathematics Support Tutor is not working they are run by two additional tutors, a Senior Lecturer in the Mathematics Department and a Research Fellow in the School of Education. As well as general mathematics support, which can be sought at any sessions, there is provision for mechanics and statistics support on specific days of the week.

Although open to, and used by, all, the service initially targeted foundation/first year students. The problems students brought varied tremendously from basic arithmetic to high-level pure mathematics. In this respect the **math**tutor materials have proved extremely useful and have been well received by the students. Increasingly more students are coming with statistical and mechanics problems, hence the focusing of some of the drop-in sessions. Unsurprisingly the students come from a variety of disciplines including Chemistry, Biochemistry, Mechanical Engineering, Sports Science, Meteorology, Earth Sciences, Medical Sciences, Mathematics and Physics.

Students are encouraged to use the mathematics resources/computers in the Skills Centre outside the timetabled drop-in times. In addition, many use the **math**tutor materials that are available on-line or use the free paper-based leaflets and reference books. One meteorology student summed up her response to the drop-in sessions:

> "*I certainly would not have got through the last semester and passed the exam without the help received in the maths drop-ins. The Centre provides me with an environment where I feel I can progress and develop my maths skills without the panic and 'maths phobia' I normally associate with anything which has numbers in it.*"

Targeted Support with Particular Groups of Learners

Another core component of the Mathematics Support Tutor's role is to work with specific groups of students making the transfer between school and university. Thus far four groups have been targeted:

1. First-Year Chemists

Many first-year Chemistry students take a 'Calculations for Chemists' 11-week course in the first Semester. Together with the course lecturer, the Mathematics Support Tutor designed a diagnostic test to be taken by these students in Induction Week. The **math**tutor materials were cross-matched to the syllabus and, throughout the course, regular examples classes and support sessions specifically for these students were run jointly by the course lecturer, a PhD student and the Mathematics Support Tutor. These sessions, which were held in the Skills Centre, were well attended: the students enjoyed coming to the Centre, working comfortably in small groups and receiving individual advice/support from the tutors where necessary. Some sought further regular help at the drop-ins. One student said:

> "*Having the examples classes in the Skills Centre is so much better than in a lecture theatre. The rooms are comfortable and you work in small groups in a nice environment. I was able to tackle the problems at my own pace and there was always help available whenever I was stuck.*"

2. Foundation-Year Physicists

The Mathematics Support Tutor is the tutor for the foundation course, "Basic Mathematics Skills for Scientists". This is a new mathematics course which underpins the other mathematics courses the students are taking and **math**tutor materials are used as core course resources. The students range from those who have not done any mathematics for some time to others who have just left school/college with low A-Level grades. Most have found the course useful and have liked the **math**tutor materials, and the video tutorials in particular, as backup.

3. First-Year Mathematicians

In Semester 2, 2006, the Mathematics Support Tutor provided 'Booster' sessions in the Skills Centre for first-year mathematicians who have failed some of their key mathematics exams in Semester One. At the beginning the students reflected on what topics they were good, average or poor at. Areas of particular concern were addressed in subsequent sessions. The Mathematics Support Tutor tried to build the students' confidence in their own mathematical ability and encouraged them to use the **math**tutor material independently to target other gaps in their learning or understanding.

4. First-Year Sports Scientists

Finally, the Mathematics Support Tutor is course tutor for a Basic Mathematics course for first-year sports scientists. 120 students take this course and mathematics skills range from those who have struggled to pass GCSE mathematics to the confident grade 'A' student: a challenging diversity with which many academics are familiar. A diagnostic test is taken by the students before commencing the course. Depending upon the results, the students have to attend all or only some of the lectures. All students are required to come to the examples classes and to do the weekly assignments. To pass the course the students have to pass both the assignment component and the final exam. Students are closely monitored and are encouraged to come to the Mathematics Support Centre drop-in sessions. One student said:

> "*Liz is so enthusiastic and helpful. She tries to take a personal interest in you and makes maths more accessible. She is the human face of maths and should teach all maths modules.*"

Continuing and Sustaining the Service

The response to the service provided directly by the Mathematics Support Centre as well as that provided by the Mathematics Support Tutor through targeted lectures, has been overwhelmingly favourable. Moreover, increasing usage as the Centre becomes more widely known within the University is most encouraging.

The role of the Mathematics Support Tutor has expanded and developed since the Centre first opened. As well as running support sessions within the Centre they are lecturing on courses and collaborating closely with academic staff. Their background and experience of working with those of all abilities and of enthusing about mathematics in a very public arena has been particularly useful: as evinced by the sample of students' comments included above, they have managed to create an environment in which the students can develop confidence in their abilities whilst facing up to their weaknesses.

The Skills Centre has now become part of the University Library and, with help from colleagues, more funding has been made available from the University to continue and expand the mathematics support service for another two years. The Mathematics Support Tutor is now working three days a week and there is funding for extra advisor support. So, the near future is looking good.

The Manchester Mathematics Resource Centre

C. D. C. Steele

Abstract

This article describes the recent creation of the Manchester Mathematics Resource Centre, a drop-in mathematics support centre at the University of Manchester. It can be used to provide others with details of progress and pitfalls as well as to invite comment. The early activities of the Centre are outlined and some specialised enquiries are described in greater detail.

Introduction

The University of Manchester dates (in its present format) from 2004 when it was created from two predecessor universities (the Victoria University of Manchester, more commonly known as the University of Manchester, and UMIST, the University of Manchester Institute of Science and Technology) dating back to 1824. It is the largest single-site university in the UK with 13,500 staff and 35,600 students. These include 7,000 overseas students from 162 countries. The campus is about two kilometres in length in its longest dimension (north-south) with the northern end being close to Manchester city centre.

The School of Mathematics within the University was formed from the two Departments of Mathematics at the predecessor universities. Within the School, there are about 70 academic staff, 900 undergraduate students and 150 postgraduate students. Following a period of temporary arrangements, the members of the School are now housed in a new building near the centre of the campus. The School of Mathematics is proud to be involved in high-profile service teaching to much of the faculty of Engineering and Physical Sciences (EPS) and to various other parts of the University.

A drop-in Resource Centre was first suggested in January 2003. It was observed that such a Centre would be of obvious benefit to the students who visited it and, as such, to the University as a whole. Moreover, there was a belief that the profile of the School of Mathematics would be raised both within the Faculty and the University as a result of its creation. At various times during 2005, discussions took place with the associate Dean of Teaching within the EPS faculty regarding its creation.

The Early Days of the Centre

While discussions were still ongoing it was decided that preliminary sessions should be run and, in late April 2006, the Centre first opened its doors to students. A small room within one of the buildings occupied by the School of Mathematics was opened for three one-hour sessions per week in the run-up to the May/June exam period and an email was sent to all students mentioning the Centre. Interest was limited at this stage but certainly showed potential and opening hours were expanded to 11 per week from Autumn 2006. Once again, interest was a little limited although it picked up in January 2007 as sessions were organised in advance of the January examinations: despite there being two advisors in the room, there were occasions when, due to numbers, students queued for two hours before being seen by an advisor and sessions went on long past the scheduled close.

The Next Stage of the Centre

A related development concerned the award in 2005 of a CETL to the University of Manchester in the area of Enquiry-Based Learning (EBL) (www.campus.manchester.ac.uk/ceebl/). An associated application led to the refurbishment of space for the EPS Faculty EBL Centre plus an adjacent room for the Mathematics Resource Centre. This application also realised six laptop computers for use by the Resource Centre.

Accordingly, in February 2006 (the beginning of Semester 2 of Academic Year 2005-06), the Manchester Mathematics Resource Centre opened its doors in a new location. This room was within a building occupied primarily by the school of Mechanical, Aerospace and Civil Engineering, i.e. one of the schools making most use of mathematics. It was felt that a location away from the accommodation occupied by the School of Mathematics would emphasise the fact that the Centre was open to students outside the School although, obviously, with a campus the size of that at Manchester, any single location would be inconvenient for a subset of the student body.

The location refurbished for use by the Resource Centre is a lecture room seating 25 individuals. While the room is bookable through the Room Request Service (i.e. lectures may also be held there) there is an understanding that the Mathematics Resource Centre has a priority in the booking of this room and currently the Centre chooses to book the room for 20 hours per week. As well as the movable tables and chairs, there is a workbench on one side of the room, a blackboard, reasonable blackout facilities and a storage cupboard. The cupboard is used to store relevant text books, the University of Manchester Formula Tables (Steele, 2003), Helping Engineers Learn Mathematics (HELM) workbooks, calculators, and stationery. The laptop computers belonging to the Centre are kept in a secure location elsewhere and are brought out when required (to demonstrate mathematics to students, during special events, and for the benefit of advisors in quiet times).

In this new location, the Centre is open for 4 hours per day (10 am to 2 pm or 12 noon to 4 pm) during both Semesters. Sessions are divided into four one-hour slots, with each slot supervised by an advisor who is either a member of staff or a PhD student. The rota, along with the specialism of each advisor (Methods, Pure, Applied, Numerical, Statistics), is displayed on the Resource Centre web-page. There is a mechanism for students to book an appointment online and hence get priority treatment, but at most times students can simply drop-in.

The Nature of Enquiries

At a typical session, visiting students are encouraged to write down a brief description of their enquiry together with details such as their School and year of study. These details help advisors to get enquiries started and the data generated can be used to analyse demand for the centre. During an enquiry, the advisor will sit with the student and go over their query in a manner that will help them solve the problem in question and also tackle similar problems in future. In addition, the advisor may give the student a copy of the relevant HELM workbook or provide them with a reference to the topic in a particular text. Alternatively, or additionally, the advisor may use a computer to demonstrate to the student specific aspects of the enquiry, for example, the effect on a function of changing a parameter. More specialised enquiries may be referred to a different advisor. Moreover, after further reflection following a session, advisors may, on occasion, arrange a follow-up meeting. In particular, enquiries from final-year Mathematics students on specialised options may require a referral to a colleague whilst those from research students (from many Schools) may remain open-ended.

Sometimes, a student will present an enquiry which is related to a piece of coursework (this may or may not be made explicit). Whilst advisors are instructed not to answer such questions directly, they will typically provide some background mathematics so that the student will be able to solve the problem on their own, or will construct and demonstrate how to solve a related question. Occasionally the Centre runs pro-active sessions, for example addressing a group of students rather than answering specific questions. Some of these deal with topics which are common to the programmes of many students whilst others specifically prepare identified students for a follow-up programme following diagnostic testing at the beginning of the academic year.

Below we explore two examples of difficulties that advisors may encounter. The first demonstrates challenges presented by the cross-curricular nature of the Centre and the second illustrates the open-ended (and not necessary solvable!) nature of problems posed by research students.

Terminology and Differences

One issue of concern that has arisen at the Resource Centre is that students in different disciplines have different systems of notation: a student may explain an enquiry to an advisor using terminology and notation that prevents the advisor from understanding the problem in spite of them being familiar with the underlying mathematics. Equally, the advisor may solve a given problem in a style that is inconsistent with that presented in lectures. By way of an example, the following problem is typical of many enquiries from students of economics.

Find the maximum value of the function $y = 6x - x^2$
subject to the constraint $x \leq 4$ *(or equivalently,* $4 - x \geq 0$*).*

The typical approach of a mathematician would be to find the derivative with respect to *x*, to equate this derivate to zero, to solve for *x* and then substitute back to find *y*.

i.e. $\frac{dy}{dx} = 6 - 2x = 0$ *implying that* $x = 3$ *and hence* $y_{max} = (6\times 3)-3^2 = 9$.

By considering the second derivative, the mathematician would then confirm that they had identified a local and global maximum before verifying that their solution satisfied the necessary constraints.

By contrast, an economist would typically employ Lagrange multipliers. They would construct a Lagrangian equation *L* combining the given function and the constraint. In this instance,

$L(x,\lambda) = (6x - x^2) + \lambda\,(4 - x).$

They would find the partial derivative of *L* with respect to *x* and set this equal to zero before solving simultaneously along with the constraint, the non-negativity of λ and the complementary slackness condition (either λ or the constraint must be zero).

(1) *Derivative of Lagrangian:* $\frac{\partial L}{\partial x} = 6 - 2x - \lambda = 0$

(2) *Constraint:* $4 - x \geq 0$

(3) *Non-negativity of* λ: $\lambda \geq 0$

(4) *Complementary slackness:* $\lambda = 0$ or $4 - x = 0$.

The conditions for complementary slackness would be considered separately.

- *If $\lambda = 0$, then (1) implies that $2x = 6$, and hence $x = 3$ and $y = 9$.*
- *If $4 - x = 0$, then (2) implies $x = 4$ and hence (1) yields $\lambda = 6 - (2\times4) = -2$ contradicting (3).*
- *Hence the first solution is accepted implying that $x = 3$ and $y_{max} = 9$.*

The two approaches naturally yield consistent results since they employ the same underlying (but somewhat disguised) methods. However, the starkly different terminology can lead to a misunderstanding between the student and the advisor. To address this issue there are plans in place to introduce resources to enable advisors to overcome this problem.

A Research-Based Enquiry

An enquiry from a PhD student involved trying to find a function corresponding to a given distribution. The distribution in question, $n(r)$, modelled the number of particles of linear size r and was know to satisfy the following constraint:

$$\int_0^\infty r^i\, n(r)\, dr = a_i \qquad \text{for given } a_i \text{ where } i = 0,1,2,3.$$

The student had already considered a solution of the form:

$$n(r) = \exp\,(p_0 + p_1 r + p_2 r^2 + p_3 r^3)$$

but had been unable to find values for the p_i coefficients. An alternative approach suggested at the Centre was to assume a form:

$$n(r) = (q_0 + q_1 r + q_2 r^2 + q_3 r^3)\; e^{-kr}$$

and then find the constant k and coefficients q_i using the properties of Laguerre polynomials. In the end, the student successfully tried a combination of the two approaches and was able to make progress with the project (Jones & Watkins, 2008).

Current and Future Challenges

Reaching all relevant students has, at times, proved problematic due to both geographical and communication constraints.

The size of the campus means that some Schools are located a considerable distance from the Resource Centre and hence students from these Schools may not pass the Centre as part of their routine. Moreover, whilst all students have been sent emails advertising the Centre and many announcements have been made in classes, it is felt that a significant proportion of students still fail to recognise its benefits. Although the student 'grapevine' is possibly the best form of advertising, a challenge for the Centre concerns the best way to seed, grow, maintain and re-seed this grapevine, and a recent development has been an opportunity for students to sign up to a mailing list for the Centre. In addition, plans are being made to run 'outreach' visits to certain Schools in future. Such a visit would consist of a session describing the Centre, its activities and location, followed by a chance to deal with a few enquiries. The objective would be to encourage future visits to the Centre.

Postscript

Regrettably, as of February 2010, resources given to the Resource Centre have been significantly reduced and the Centre is able to operate only during the examination period rather than throughout the semester as had previously been the case.

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CHAPTER TWO

Beyond the STEM Disciplines

Mathematics for Economics: Enhancing Teaching and Learning

R. Taylor

Abstract

METAL (Mathematics for Economics: enhancing Teaching and Learning) is a three-year project funded by the HEFCE in Phase 5 of its Fund for the Development of Teaching and Learning (FDTL5). The aim of the Project is to maximise student attendance, engagement and participation in mathematics for Economics through the provision of an accessible and fully interactive toolkit of varied and flexible resources. The Project team achieved this goal through the development of an online question bank of mathematics teaching and assessment materials specifically applied to concepts in Economics, as well as interactive video units relating mathematical concepts to the discipline of Economics, and teaching and learning guides that present innovative and interactive approaches to teaching mathematical concepts to Economics students. An interactive website (www.metalproject.co.uk) was created to present the teaching and learning resources, to facilitate distance learning and to foster students' autonomy and ownership of the learning process.

The Project was directed by Dr. Rebecca Taylor at Nottingham Trent University in collaboration with Brunel University and the University of Portsmouth. The Project team also benefited from the invaluable support of three advisory partners: The University of Birmingham, the **math**centre team at Loughborough University and the Educational Broadcasting Services Trust.

Introduction

Since 1990 the teaching of mathematics to Economics students has become increasingly challenging for universities across the sector, regardless of entry qualifications. Many Economics (or economics-related) programmes in the UK now have a mixed intake of students with either A-Level or GSCE mathematics backgrounds (or equivalents) and the latter may lack fluency in the use of mathematical concepts. In addition, the widening participation initiative has led to an even greater diversity of student backgrounds, particularly in relation to mathematical skills. Consequently students often do not have the mathematical ability required to successfully complete their first year of study.

Such heterogeneous mathematical skills, coupled with the increasing national focus on interactive, student-focussed and inclusive learning are addressed by this project through a three-pronged approach to learning that meets the changing needs of Economics students. The project outcomes comprise a series of innovative and interactive materials which build upon past work from previously funded projects including PPLATO (FDTL4), HELM (**math**centre), Lifesign (JISC) and Mathematics Support at the Transition to University (FDTL4).

The Project, launched in May 2008, was directed by Dr. Rebecca Taylor at Nottingham Trent University, in partnership with the University of Portsmouth and Brunel University. These institutions have expertise in different aspects of the Project deliverables, use many methods of delivery, and recruit diverse groups of students. The integration of mathematics with Economics means that it was essential to the project's success that the consortium combined expertise from both of these areas. Brunel University's experience developing on-line mathematics materials combined with the subject specific knowledge of the Economics teams at Nottingham Trent University and the University of Portsmouth created a consortium that could effectively address the needs and challenges faced by both lecturers and Level 1 Economics students across the entire university sector.

The aim of the Project was to maximise student attendance, engagement and participation in mathematics for Economics through the provision of an accessible and fully interactive toolkit of varied and flexible resources. The Project team delivered this through a number of key objectives which included:

- Creating an online question bank of mathematics teaching and assessment materials specifically applied to the discipline of Economics;
- Developing 50 video units using streaming video that relate mathematical concepts to the discipline of Economics;
- Developing 10 teaching and learning guides that provide an extensive bank of teaching activities for both small and large groups that cover all aspects of Level 1 mathematics for Economics;
- Designing an interactive website to present the teaching and learning resources, to facilitate distance learning and to foster students' autonomy and ownership of the learning process.

Through these objectives the Project team were committed to developing diverse and innovative assessment opportunities for Economics students, engaging students in a clearer understanding of mathematics for Economics, monitoring student learning during, and beyond, the lifetime of the Project, and disseminating and embedding Project outcomes through methods that would maximise awareness, understanding and implementation.

Video Units

The University of Portsmouth, in association with StreamLearn, developed the Project's 50 video clips, which include:

- 'Real world' examples illustrating principles of Economics;
- The presentation of data derived from 'real world' examples;
- Formulae applied to the data to answer questions raised in the introduction;
- Animation boards that are used to present the solutions to relevant mathematical problems.

The 50 films illustrate the main topics covered in a typical Level 1 module/unit. In each example a real world scenario is presented which is drawn from an industry or macroeconomic problem. These are filmed in many different locations across Europe and the USA. This often involves interviews with managers or academics so that students are presented with real problems. Students are then shown that the most efficient way to analyse these problems is by using basic mathematics. The mathematical solutions are presented electronically in a way that enables students to see how each step contributes to the solution.

Online Question Bank

Brunel University was responsible for the development and delivery of the online question bank. Each of the questions is a short programme that generates all components of the question at runtime. These are called *question styles*. Each question style incorporates several random parameters whose values range over specified values, words or question scenarios; thus each question style generates millions of potential *question realisations* to be delivered to the student.

A range of *question types* has been used, mainly: multiple choice, multiple response, numerical input, responsive numerical input and true/false/undecidable. The random parameters are used to generate the question wording, the correct answer, the distractors, the (usually extensive) feedback, and the question description metadata and outcome metadata (both primarily used in the answer files).

Mathematical expressions that carry through the random parameters are generated at runtime using MathML. Graphs and diagrams that carry through the random parameters are generated at runtime using Scalable Vector Graphics (SVG). The display of all elements is under the control of the individual student, who can set his/her own preferences for font size and family, and font and background colours. This accessibility feature is believed to exceed SENDA (Special Educational Needs and Disability Act**,** 2001) requirements.

The questions have been widely disseminated and feedback from students and academics has been very positive. Extensive formative testing has been carried out at Brunel University; a suite of formative tests were made available to 340 Level 1 Economics students during the 2007/8 academic year. Although no answer files were written, informal feedback (especially amongst those students without A-level Mathematics) was very positive and the results of the second class test exceeded expectations **–** this may be due in part to the tests provision of extensive feedback.

Teaching and Learning Guides

Nottingham Trent University was responsible for the development and delivery of the METAL teaching and learning guides. The guide specifications and activities were also developed at Nottingham Trent. The authorship of the guides was then contracted out to Economics lecturers at five UK universities in order to engage more end users in the development process.

The teaching and learning guides are written primarily for lecturers and tutors and present innovative and interactive approaches to teaching mathematical concepts to Economics students. Each concept featured is linked to a related video unit and the relevant section of the online question bank. The guides include:

- The presentation of specific mathematical concepts;
- Top tips;
- Teaching and learning suggestions;

- Seminar activities which are also available as separate files in .pdf or Microsoft Word format.

These guides have been popular with initial users of the METAL Project resources. Students have provided very positive feedback on the use of activities and on best practice in large and small group teaching sessions.

Website

The METAL Project website was created by Nottingham Trent University. The site is clearly structured and provides information about the Project, the team and relevant events. The central focus of the website is the 'Resource Room' which contains all of the online resources developed for the Project. The teaching and learning guides, video clips and question bank are all available to use online or are easily downloadable for use in a small or large group teaching session. The flexibility of the resources and the attention to detail that has gone into ensuring that the resources are user-friendly are frequently commented on by lecturers and students.

The website now includes a fourth resource which is a set of 15 case studies that help students to understand the relevance of mathematical concepts to issues such as student debt, healthcare, gambling and mortgage decisions. This additional resource was funded by the Joint Information Systems Committee (JISC) and has enabled the Project team to provide lecturers with a complete package of resources to help them engage students in the study of mathematics for Economics.

A key feature of the METAL website is that all resources have links and references to the other related resources on the site. This enables the lecturer to provide students with a more complete and inclusive learning experience.

Evaluation

The Project team commissioned an independent evaluation which involved a survey and individual interviews with a number of lecturers of mathematics for Economics. A striking feature of the survey was the unanimous and positive support which respondents gave to the METAL Project. All participants thought that the Project was creative and innovative and, while most suggested that METAL had set itself ambitious targets, all the respondents thought that the Project had achieved these goals.

Respondents independently identified different contexts and applications for the METAL resources. This confirmed that the materials can be flexibly used in a wide range of settings and can achieve a significant and positive impact upon students' learning.

The key strengths identified in the Project evaluation report include:

- A valued and clear project brief underscored by strong Project leadership and management;
- Helpful and well-organised workshops which contextualised the resources and offered both time and support for lecturers to trial the METAL resources;
- The high quality of resources and their wide applicability to the teaching and learning of mathematics within Economics courses;

- The resources and materials could potentially have a wider application beyond undergraduate Economics, for example in programmes in accounting and business;
- The applied nature of the resources was seen to address directly the issue of making mathematics easier to understand;
- The resources can be used to meet a wide range of teaching and learning needs;
- The resources and materials are well written and offer interesting and engaging activities which accommodate different learning styles, for example kinaesthetic, auditory and visual.

A second evaluation report has been commissioned for late 2008 to gain information about how the resources are being used to enhance the student learning experience.

Dissemination

The METAL Project team developed and implemented a very intensive campaign to disseminate and embed the project resources within the Economics community. These activities included conferences, seminars, promotional materials, advertising and departmental meetings. Further feedback through the development stage of the project was provided by lecturer and student focus groups. The team also delivered a series of 16 workshops to demonstrate the resources directly to end-users. These workshops enabled the team to discuss the different ways that the resources can be incorporated into specific teaching sessions.

Each of the 16 workshops was hosted by a different institution and included participants from the host institution and lecturers of mathematics for Economics from other institutions within the region. Workshops were well attended and participants gave very positive feedback on the resources.

The final project website launched in 2008 with a further dissemination drive through advertisements, mailshots, emails and a final round of departmental meeting presentations. These methods of communication have all, throughout the lifetime of the Project, proven to be effective means by which to communicate the Project developments to lecturers of mathematics for Economics across the UK.

Mathematics and Statistics Skills in the Social Sciences

G. R. Gibbs

Abstract

The issues concerning numeracy and quantitative skills that exist for social scientists are somewhat different from those affecting many within the natural sciences and technology-related disciplines. In general students do not need to model systems algebraically or symbolically although they do need a good sense of number (scale, size, etc.) and an understanding of some of the logical principles and thinking that underlie mathematical proofs. The main area of application of these skills is in research methods and statistics.

Quality Assurance Agency (QAA) benchmarks and the Economic and Social Research Council (ESRC) Training Guidelines for postgraduates are very clear about the importance of methods and statistics in the social science disciplines. However, key surveys suggest that there is 'a crisis of numeracy' in social science disciplines. Many students are ill-equipped to undertake quantitative work and there is a shortage of suitably qualified teachers. The response by academics has been, in part, to provide a range of mathematics support for students who need it. Alongside this, teachers have adopted a range of approaches to teaching quantitative methods including teaching statistics using formulae, teaching statistics using step-by-step instructions, and even teaching statistics without either calculations or formulae.

Mathematics in the Social Science Curriculum

The social sciences constitute a broad range of disciplines and not surprisingly there is considerable variation in the degree to which quantitative approaches are used. Many social science disciplines' mathematical concerns focus primarily on numeracy and mathematics within research methods and statistics: this is reflected in the QAA benchmark statements for these disciplines (QAA, 2007). These benchmarks represent each discipline's own perception of curriculum content at undergraduate level. (Although there might be sophisticated use of mathematics and quantitative methods at postgraduate or research level, many take the view that it is not necessary for all undergraduates to be proficient in these approaches.)

The reference to quantitative work within the benchmark statements falls into three groups. For some disciplines, for instance Politics, Education, Social Anthropology and Area Studies, there is little mention of research methods and no reference to quantitative methods. The majority of disciplines, for instance Human Geography, Sociology, Social Policy, Social Work, Biological Anthropology, Business and Management, Criminology and Linguistics, adopt what might be called a 'Basic Research Methods' approach: students are expected to study both qualitative and quantitative research methods as well as some basic statistics. For example the Education benchmark statement suggests students should "*have an ability to interpret simple graphical and tabular presentation of data and to collect and present numerical data*".

Two disciplines expect greater mathematical competence and address both numerical skills and quantitative techniques more explicitly and in greater detail in their benchmark statements. The first is Economics where proficiency in quantitative methods and econometrics, including knowledge of appropriate techniques for structuring, representing and analysing data, is central. The second discipline to adopt this ‘maximal approach’ is Psychology. The benchmark document states clearly that students should “develop an understanding of the role of empirical evidence in the creation and constraint of theory and also in how theory guides the collection and interpretation of empirical data” and that they should acquire “knowledge of a range of research skills and methods for investigating experience and behaviour, culminating in an ability to conduct research independently”. At the modal level, a student should be able to “demonstrate a systematic knowledge of a range of research paradigms, research methods and measurement techniques, including statistical analysis, and be aware of their limitations”.

At the level of postgraduate teaching, a good indication of the centrality of quantitative methods can be seen in the Research Methods Training Guidelines produced by the Economic and Social Research Council (ESRC 2005). These all include reference to quantitative methods and statistics and they specify the content of MSc training which is compulsory for all ESRC funded students.

What is the Problem?

The centrality of quantitative methods and numeracy and its compulsory status in much of the social sciences presents particular problems. Put simply, research methods (and especially quantitative methods) are typically unpopular with students – and indeed with many members of academic staff! Although some quantitative methods are compulsory within most of the social sciences, many students will avoid them if given the opportunity, especially in the second and third year of undergraduate degrees when they are given flexibility. Moreover, when taking compulsory quantitative elements of their courses, many students experience anxiety, and demonstrate a lack of arithmetical ability or sense of number skills, as well as poor probabilistic thinking and logic skills.

In addition to knowledge and understanding of statistical techniques, the mathematical skills that social scientists might be required to demonstrate fall into three broad categories:

- Numeracy, including a familiarity with numbers, a sense of size and scale, and the ability to undertake simple calculations;
- Symbolism and algebra, including the ability to substitute numeric values into algebraic expressions and hence evaluate them;
- Logic and argument including probabilistic thinking and other forms of logical reasoning.

With the possible exception of Economics, most social sciences do not require students to possess a full range of mathematical skills. Whilst numeracy, sense of number, and logical thinking are generally considered to be important skills for any quantitative work, in general, social sciences students are expected to have no more than limited skills in algebra. Unfortunately, there is evidence in many disciplines that students are ill-equipped in all three respects.

Table 4	
Calculate each of the following:	
√ 0.09	
Answers	%
.03	43
.3	17
.81	2
Other	12
No answer	26
0.02 x 0.12	
Answers	%
.0024	28
.24	27
.024	14
.06	3
Other	12
No answer	15
40 ÷ 0.8	
Answers	%
50	43
.5	10
320	3
.1	2
Other	24
No answer	19
Note: highlighted item is the correct answer	

Figure 1. Answers given to four questions in the maths test for psychology students.

Mulhearn and Wylie (2005) have undertaken a detailed survey of the level of mathematical ability amongst entrants to Psychology degrees. In this study a mathematics test was given to students in eight British universities (including both pre- and post-92 institutions). The test examined the mathematical ability expected of a student with an A-Level in Psychology. Mulhearn and Wylie found a mean correct score of only 13.75 out of 32 (43%) with female students consistently performing significantly worse than males; an important finding as 80% of Psychology students are female. Common errors included mistakes in dealing with decimals, problems with simple algebra, inaccurate graphical interpretations and false probabilistic thinking. Figure 1 shows a table of responses to four questions set by Mulhearn and Wylie. The test was the same as one used in previous studies undertaken in 1984 and, hence, the authors were able to compare the results found in 2004 with those found twenty years earlier. They concluded that the results suggested a marked decline in mathematical and numerical competence amongst A-Level Psychology students.

A similar situation can be found in other social science disciplines. For instance, Williams (2002) reports a study of teaching staff in Sociology which was undertaken by surveying departments, delegates at a British Sociology Association (BSA) conference, and attendees at consultation days. Williams found that all the departments surveyed offered at least some quantitative methods and that this constituted between 5 and 15% of the degree. However, staff felt that there was a crisis of numbers in British Sociology, with students unenthusiastic about quantitative methods and with many barriers to effective teaching. 75% of Sociology staff surveyed at the British Sociological Association conference thought that students chose a degree in Sociology in order to avoid having to deal with numbers and two thirds thought Sociology students were not numerate. The staff consultation days, undertaken later, reinforced the view that students perceived quantitative work negatively. Many staff

Calculation 5.1 continued

Table 5.1 Steps in the calculation of the standard deviation

Scores (X) (age in years)	**Scores squared (X^2)**
20	400
25	625
19	361
35	1225
19	361
17	289
15	225
30	900
27	729
$\Sigma X = 207$	$\Sigma X^2 = 5115$

Table 5.1 lists the ages of nine students (N = number of scores = 9) and shows steps in calculating the standard deviation. Substituting these values in the standard deviation formula:

$$\text{standard deviation} = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{N}}{N}}$$

$$= \sqrt{\frac{5115 - \frac{(207)^2}{9}}{9}}$$

$$= \sqrt{\frac{5115 - 4761}{9}}$$

$$= \sqrt{\frac{354}{9}}$$

$$= \sqrt{39.333}$$

$$= 6.27 \text{ years}$$

(You may have spotted that the standard deviation is simply the square root of the variance.)

Figure 2. The traditional approach to teaching statistics in Howitt, D and Cramer, D. (2005).

indicated that this perception was often perpetuated by colleagues: those teaching qualitative methods might typically begin their sessions with a diatribe against quantitative methods. Participants also identified a shortage of qualified and motivated staff. Whilst one has to be cautious about responses from a consultation of this kind, which would clearly attract teachers supportive of quantitative approaches, the view that there is a shortage of staff able to teach quantitative methods is shared by the ESRC, which in the last few years has operated various schemes aimed at increasing the number of postgraduate research students undertaking quantitative projects.

Students' negative views about quantitative methods and about their own mathematical abilities have been found by other studies and in other coutries. For example, Murtonen and Lehtinen (2003) examined education and sociology students in Finland and found that statistics and quantitative work were perceived as more difficult than other topics. They found some evidence for a correlation between perceived difficulty and how abstract the student thought the subject to be, with statistics and mathematics seen as difficult and abstract whereas the students' own degree subject and language modules were both perceived as relatively easier and more concrete.

The 'group' row is the between-groups statistics, and is the row of interest. Our analysis shows us $F(2,33) = 9.92$, $p < 0.001$. Remember in Chapter 5 we explained that a correlation coefficient could be squared in order to show the percentage of variation in scores on y accounted for by scores on x? Well, partial η^2 is a correlation coefficient that has already been squared. So in this case, we can simply read the number in the 'eta squared' column. The interpretation in the case of partial η^2 in this ANOVA is to say that 37.5% of the variation in driving ability is accounted for by which alcohol condition the participants were in

Tests of Between-Subjects Effects
Dependent Variable: driving ability score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	145.167[a]	2	72.583	9.915	.000	.375
Intercept	1980.250	1	1980.250	270.500	.000	.891
GROUP	**145.167**	**2**	**72.583**	**9.915**	**.000**	**.375**
Error	**241.583**	**33**	7.321			
Total	2367.000	36				
Corrected Total	386.750	35				

a. R Squared = .375 (Adjusted R Squared = .337).

The 'error' row contains the figures relating to the within-participants variation

Levene's Test of Equality of Error Variances[a]
Dependent Variable: driving ability score

F	df1	df2	Sig.
.215	2	33	.808

Shows that the variances of the three groups are not significantly different from each other, therefore we have met the assumption of homogeneity of variance

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept+GROUP

Figure 3. The 'Black Box' approach adopted by Dancey and Reidy (2004).

The Response by Academic Staff

Academics in the social sciences have responded to these problems in two ways. The first is the approach, familiar in many disciplines, which addresses the students' deficits and needs directly with additional support. This is provided by academic members of staff who re-assure students, improve their confidence and give individual tutorial support. In addition, much support is now given through specialist units (as discussed in other papers in this volume) based in schools, departments, faculties or at the university level.

The second approach has been to teach quantitative techniques, and statistics in particular with significantly reduced emphasis and minimal reliance upon mathematical skills, thereby reducing the amount of calculation, arithmetic, and manipulation of algebraic formulae expected of students. This approach has been propagated by the widespread use of statistical software (usually SPSS) so that a 'Black Box' attitude can be adopted: the software does the calculation and academic staff focus upon teaching the appropriate choice of statistical tests and the interpretation of results. Examples of both approaches appear in current textbooks. For instance, as illustrated in Figure 2, Howitt and Cramer (2005) adopt the traditional approach demonstrating how to substitute values into algebraic

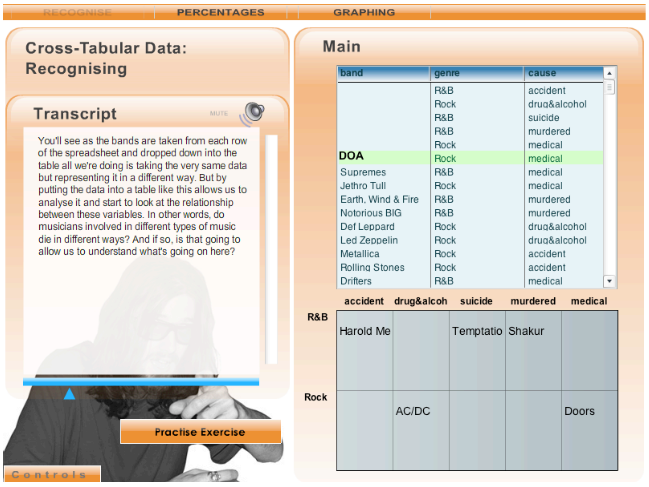

Figure 4. Reusable Learning Object on how to convert survey or experimental data into cross-tabular data (http://www.ucel.ac.uk/rlos/cross_tab_data/main.html)

formulae. An example of the 'Black Box' approach is illustrated in Figure 3 in an excerpt from *Statistics without Maths for Psychology* Dancey and Reidy (2004). Actually the title is misleading: it does not mean "without maths" but rather "without calculation and algebraic expressions" as students still need to understand some simple mathematical concepts.

Possible Future Developments

There are competing pressures concerning the place of quantitative skills in the social sciences. On the one hand, the ESRC is clearly pushing to ensure that sufficient numbers of the next generation of social scientists are trained in quantitative methods. On the other hand, there has been significant growth in interest in qualitative methods in the social sciences in the last 20 years, especially reflecting the 'turn to language' with increased research interest in rhetoric, narrative, discourse and representations of identity. Additionally, the social sciences face the dual challenges of students lacking (and being resistant to the acquisition of) essential mathematical and statistical skills coupled with insufficient numbers of suitably qualified academic staff to teach these skills.

To address these tensions, two developments are key: first, the expansion of central mathematics support facilities to help social science students, and second, the development of better materials and resources for such students. There is great potential for e-learning to respond to this second need. It is vital that these new resources do not simply replicate the kinds of classroom experience that some students find so intimidating and demotivating. Rather, they should embed conceptual learning in relevant, interesting and concrete models as illustrated in Figure 4.

To conclude on a more positive note: whilst the concerns regarding quantitative skills amongst social science undergraduate students are keenly felt, there is some indication that, at least at the research level, the growing interest in mixed methods might ameliorate the all too frequent antagonism between qualitative and quantitative methods.

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SIMPLE: Helping to Introduce Statistics to Social Science Students

C. O. Fritz, B. Francis, P. E. Morris, & M. Peelo

Abstract

Social science students are typically less than positive about developing quantitative skills. This paper reports on efforts, with support from the Economic and Social Research Council (ESRC), to identify and address problems that arise when teaching quantitative analysis skills to social science students. Problems include: the misperception that quantitative skills are not relevant to their field; wide variation among students in their basic skills; and lack of resources to support the learning of quantitative skills. Through the SIMPLE (Statistics Instruction Modules with Purposeful Learning Emphasis) project, a mechanism is provided to help tutors address these problems. SIMPLE is a practice-based system for teaching statistical concepts and skills to social science students and is based on principles from psychological research about learning. The project has two main components:

- Software that will organise, schedule and track performance on online teaching units with user-friendly interfaces for both tutors and students;
- A small set of fully defined online modules, including explanatory materials and embedded formative and diagnostic assessment.

Both the software and the modules are being developed as a pilot project and are being used for first year psychology students in 2007-2008. They will be made available to interested parties in the summer of 2008.

Background

Social science students are typically motivated by a desire to study and learn more about people in some context, whether they have chosen Anthropology, Criminology, Educational Research, Geography, Politics, Psychology, Social Work, Sociology, or another social science field as the home for their studies. All of the social sciences are research-based and include quantitatively oriented research; in the UK all of these undergraduate disciplines are expected by the Quality Assurance Agency (QAA) to include a quantitative component.

Students' Preparedness and Attitudes

Students are not always well prepared for learning statistics. Despite efforts to introduce data handling and basic statistics in a meaningful way in the primary and secondary school curriculum (e.g., Gibson, Marriott & Davies, 2007), many students arrive at university ill-prepared to engage with issues of research design and data analysis. Moreover, most social science students have intentionally avoided quantitative study beyond school requirements (i.e., GCSE or equivalent) and have allowed the knowledge and skills they developed at that level to atrophy. Our surveys of incoming students' mathematical skills

Question content	% correct	Notes
1. Ordering three numbers		
a. whole numbers: 23, -20, 18	100	
b. decimal fractions: .3, .13, .20	**57**	
c. simple fractions: $^1/_7$, $^1/_9$, $^1/_3$	99	
2. Estimation		
a. whole number multiplication: 38 x 21	72	
b. whole number division: 214 ÷ 11	82	
c. decimal fraction division: 917 ÷ .48	**39**	Half of the errors estimated 917 x .48
3. Number facts and mental arithmetic		Did you *know* the answer or did you calculate it?
a. single digit multiplication: 3x6, 8x4, 2x9	97	89% knew the answer
b. similar division: 54÷9, 49÷7, 5÷5	91	76% knew the answer
c. simple fraction multiplication: 12 x $^1/_3$	78	35% knew the answer
d. simple division w/decimal fraction: 4÷.5	**59**	38% knew the answer. A further 26% "knew" incorrectly that the answer was 2 (i.e. 4x.5)
4. Written arithmetic		
a. whole number multiplication: 17 x 42	**65**	
b. whole number division: 126 ÷ 7	82	
c. division by a decimal fraction: 45 ÷ .15	**24**	
d. whole number subtraction: 123 – 78	87	
e. Order of operations: 2 + 3 x 10	**38**	
5. Mathematical notation		
a. summation/average: $\frac{\sum(2,2,4,6,6)}{5}$	80	
b. squares: $4^2 + 3^2$	82	
c. square root: $2 + \sqrt{25}$	95	
d. cube root: $\sqrt[3]{27}$	**44**	
6. Algebra		
a. solve for X: A + X = B	**57**	
b. solve for A; The symbol '*' means multiply (A * X) + (A * Y) = Z	**17**	
c. multiple choice, expand $(X + Y)^2$	**35**	
d. multiple choice, expand A(B + C)	82	

Table 1. Basic mathematics quiz performance data for 77 incoming students at Lancaster University. The order of the questions in the quiz matches that of the table. Where there was just one question (e.g., 1a) % correct is the percentage of students who answered the question correctly. Where the result is an aggregate of a few questions (e.g., 3a), % correct is based on calculating a percentage correct for each student and then averaging those across students. Low performance items (less than 2/3 correct) are in boldface.

show deficits in estimation and arithmetical skills, and substantial problems with any work involving decimal fractions or algebra at the simplest level; see Table 1 for details. Many students report being aware of their lack of foundational knowledge, and being resentful of and discouraged by tutors' assumption that they have basic skills and knowledge (Folkard, 2004). To make matters somewhat worse, there is evidence that self-evaluation is an optimistic measure and that most students are worse off than they either indicate or believe (Bynner & Parsons, 2006, p103). Furthermore, despite public assurances that secondary school standards have been maintained, data suggest that today's secondary schools are producing lower levels of mathematical fluency than in the past (Mulhern & Wylie, 2004; Savage & Hawkes, 2000).

Students often do not understand the value and relevance of statistics; they may see the quantitative aspect of their course as unrelated to, or at least separate from, the discipline they enrolled to study (Payne, Williams, & Chamberlain, 2004). Thus, many students approach most of their courses with active and enquiring minds, but approach quantitative elements of their programme with disinterest. To further aggravate matters, some staff within the discipline hold similar attitudes towards the relevance of quantitative skills and they make these views known to the students. Students' perception of quantitative analysis as somehow separate from their discipline is undoubtedly related both to their tendency to perceive statistics as formulaic and arithmetic, and to their reluctance to understand or engage in interpretation (Ben-Zvi & Garfield, 2007).

Research on students' attitudes towards statistics (e.g., Cashin & Elmore, 2005; Wise, 1985) suggests that these two dimensions – students' perceptions of their own preparedness and ability, and their perceptions of the value and relevance of statistics – are important to understanding students' learning of statistics (but see also Schau, Stevens, Dauphinee & Del Vecchio, 1995 for a four-dimensional approach). Perhaps more importantly, they are positively correlated with students' learning as measured by their course performance. It may be interesting to note that men and women as populations do not differ in their attitudes toward statistics nor in their achievements (Cashin & Elmore provide a brief review, p.519).

Students' lack of preparedness impacts both on how well they can do the tasks set before them and also on their attitudes in approaching the tasks. Bandura's social learning theory predicts that where students feel less competent, they will invest less effort and determination and will learn less. Thus, it is not surprising that students respond differently to confusion in statistics than in other aspects of their discipline. In focus groups, students reported that when they lacked initial understanding in other aspects of their discipline, they actively approached the topic in order to resolve the confusion, but when they lacked initial understanding in statistics, they tended to withdraw or to wait to see if someone would explain away the confusion. When matters did not become clear quickly enough, they reported experiencing frustration with the topic, driving them away from it.

Teaching and Resourcing Issues

The teaching of statistics in the social sciences is also somewhat challenged in terms of teaching staff and teaching resources. Teaching staff are either social science discipline specialists, with a sub-specialty or interest in statistics, or statistics specialists, who may have a sub-specialty or interest in the social science discipline. Most social science departments with qualified departmental staff for teaching statistics are likely to have just one or two such people (Mills et al., 2006), which can create a sense of isolation in teaching statistics and may present difficulties when attempting to arrange sabbatical leave. Where statistics tutors come from outside the discipline, students may have difficulty making the necessary connections between their statistics courses and their discipline and the separation of the statistics tutor from the discipline may reinforce the view that statistics is not really a part of their discipline.

Resources are typically more limited for social science disciplines. For instance, in England and Wales, the social sciences are typically funded at band D, the basic fee per student, whilst Engineering and the physical sciences are typically funded at band B, 1.7 times the basic rate. However, the teaching of quantitative analysis skills typically requires additional teaching time for practical work as well as computer laboratories to enable students to manage and analyse data in class, and funding band D does not provide for these additional teaching hours nor for the specially equipped facilities.

The Need for Quantitative Skills

Given all of these challenges, combined with the need to both attract students and to ensure that they graduate with good degrees, it may be tempting to some programmes to neglect training in quantitative skills, in favour of purely qualitative research methods. But to do so would be a disservice to the students' ability to study and learn and ultimately to their career prospects, as well as to future research in the disciplines.

Students need to be able to read and understand research and evidence-based claims both within their discipline and more broadly in the daily news; without quantitative research skills they will be unable to understand or evaluate published research and journalistic claims. For instance, on a very elementary level, when claims are made about *average income*, people without some understanding of basic statistics are likely to assume that it refers to the amount that most people earn (the mode), or the amount where half of the people earn more and half earn less (the median). With a minimal understanding of statistics and awareness that incomes are positively skewed, people can better interpret the relevance of average income vs. median income to an argument. Students studying a social science also need to be able to read and evaluate published research in their field; without an understanding of design and quantitative analysis, the literature they can access will be severely limited, leading to a distorted view of their field.

The disciplines also cannot afford to rely on researchers without a fuller understanding of the issues and the options surrounding the selection and implementation of different research methods. Obviously, effective researchers must be able to read and evaluate research, like the students above, but more broadly and more deeply. The social sciences employ a wide variety of research methods, and the best researchers will be able to evaluate a research question and research context in order to select the most appropriate method(s). Thus, the disciplines need researchers who are well versed in both quantitatively- and qualitatively-oriented research methods.

Similarly, research careers, whether in academia, government, or business, will inevitably suffer without adequate grasp of quantitative research methods (Purcell, Elias, Durbin, Davies, & Warren, 2006). Even for students who do not pursue research careers, quantitative skills are valuable. Data from Bynner and Parsons (2000) show that poor numeracy skills are more closely related to poor employment prospects than are poor literacy skills.

SIMPLE: Statistics Instruction Modules with Purposeful Learning Emphasis

The SIMPLE project is one of five pilot projects funded by the ESRC in 2007-2008 as part of an initiative to seek ways to improve quantitative skills development among UK social science students. The project includes development of a pilot system for online, interactive instruction in statistics and 3-4 instructional units. These units are intended to provide a useful supplement to the lectures, handouts, worksheets and/or textbooks that might already be in use in a given course. Pilot units include one on graphs (including some review of descriptive statistics), one on significance testing, one on correlations, and one on the sign and *t* tests. Following completion of the project, the software and the units are available to interested parties at any university.

The software and the units are designed to embed several basic learning principles:

- *Practice benefits learning:* Early testing, before new ideas are lost, promotes learning. Moreover, practice testing is more effective than re-studying or, obviously, than doing nothing.
- *Spacing benefits learning*: Presenting and testing material, moving on from that material, and returning to it promotes understanding and retention of the material. Returning to material after a break is more effective than studying it all at once or, obviously, than not having the additional study opportunity.
- *Self-efficacy influences learning*: Students are more likely to be correct on early practice tests, and this success demonstrates to students that they can succeed at studying the subject.
- *Metacognitive development can improve learning*: Use of practice tests, with embedded reviews, enables students to monitor more effectively what they have successfully grasped and what they still need to master. Improving students' monitoring skills enables them to take more effective control of their learning.
- *Learning one concept at a time improves retention*: When students are asked to learn statistics in the context of a complex aspect of their newly adopted discipline, it is somewhat like learning an unfamiliar philosophy in an unfamiliar language. When both the target concepts and the context used for the lesson are unfamiliar, the challenge is too great. Using familiar contexts enables students better to identify the statistical ideas to be learned.

A SIMPLE unit is somewhat like a slideshow, but with the facility to ask questions of the student, and to branch to different slides based on the student's answers, and to record students' progress. SIMPLE units run on a web server, and are accessible to PCs or Macs, anywhere the internet can be accessed.

Students work through each unit at their own pace. If a student makes an error or does not know the answer to a question, that student will see additional slides, providing more background, more examples, or perhaps an alternative approach. Within the additional slides there may be further questions, perhaps with more scaffolding than had originally been given. Following this 'supplementary loop' the student returns to the original question and has another opportunity to answer it. If the answer is still not correct, further tuition is provided in additional slides before attempting the question for a third time. Students who quickly grasp the concepts and skills and answer questions correctly when they first appear will complete the unit having seen fewer slides than students who need more detailed tuition. In this way SIMPLE approximates the one-on-one tutorials that many students want and that benefit confused and uncertain students (Folkard, 2004).

Tutors are able to use the units built in the pilot project, to modify those units for their own classes, and to build units of their own; an online interface allows tutors to build or modify units from familiar formats: slideshows and spreadsheets. Moreover, they are able to monitor the progress of specific students, specific parts of a unit, or the entire class on a full unit. Reports of students' progress are provided in spreadsheet format, enabling tutors to further extract and analyse the data in any way they choose.

Postscript

Both the software and the modules described above were developed as a pilot project. They were trialled with first year psychology students in 2007-2008 and re-used in 2008-2009. Without ongoing support, the software has since developed compatibility problems with updates to operating systems and browsers, but the modules are being re-developed to run as quasi-intelligent slideshows. The slideshows will be made available to interested parties in the summer of 2010.

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Acknowledgements

The SIMPLE project is funded by the Economical and Social Research Council’s (ESRC) initiative to expand and encourage undergraduate teaching in quantitative methods RES-043-25-0007 and by the Lancaster Postgraduate Statistics Support Centre for Excellence in Teaching and Learning, funded by HEFCE. The ESRC initiative is part of a set of proposals developed jointly with HEFCE, the Higher Education Funding Council for Wales (HEFCW) and the Scottish Funding Council (SFC).

CHAPTER THREE

Institutional Priorities

Mathematics Support in a University College and Research into Students' Experiences of Learning Mathematics and Statistics

S. J. Parsons

Abstract

Since the late 1990s there have been concerns about student difficulties with mathematics, statistics and general numeracy. At Harper Adams University College, a small specialist institution, all students are required to study statistics during their chosen course; the majority do this reluctantly. Engineering students are required to learn mathematics and while most appreciate the necessity of the subject, many still find it difficult. Links were shown between these difficulties and poor College student progression in the past. In response, in academic year 2001/2, curriculum changes were made and a part-time mathematics support provision was introduced and progression rates improved significantly. This provision has since been developed and extended. Additionally, information regarding students' confidence in their mathematical skills, as well as their previous mathematical experience and their perception of their ability, was gathered through questionnaires between 2004 and 2007.

This paper outlines the mathematics support provision available to students. Moreover, through analysis of the student questionnaires and comparison across years of College data on attainment and retention, it explores the impact that this provision and the accompanying curriculum changes have had on student retention as well as students' academic performance and their reported learning experience.

Introduction

Widespread concerns over students' difficulties in mathematics have been expressed by many universities, employers and the Government over the past decade. These concerns have been highlighted in numerous reports and articles. 'Making Mathematics Count', the Government Inquiry into Post-14 Mathematics Education, identified three key issues of major concern with school mathematics, one of which was

> *"the failure of the current curriculum, assessment and qualifications framework to meet the needs of many learners and to satisfy the requirements and expectations of employers and higher education institutions."* (Smith, 2004).

Ken Boston, Chief Executive of the Qualifications and Curriculum Authority (QCA), has described the teaching, curriculum and assessment of mathematics as "*one of the most challenging areas in contemporary education."* (Boston, 2006). Furthermore, Roberts (2002) expressed concerned over the supply of skills for science, engineering and technology for the national economy. Savage and Hawkes (2000) provided evidence that the mathematical skills of university entrants had declined over the years despite equivalent A-Level Mathematics grades. A Harper Adams study of student progression across the College linked student withdrawals with low GCSE Mathematics grades (Cowap,1998).

In the late 1990s student progression at Harper Adams was reduced by poor performance in Mathematics and Statistics modules: the 1999/2000 cohort of first-year Engineering students suffered a particularly high proportion of failures in compulsory Mathematics modules whilst similar concerns existed about pass rates in compulsory Statistics modules across the College. In response, Engineering mathematics modules were redesigned to include revision of essential mathematics, topics in which in-coming students could no longer be assumed to be confident. These changes were made without any erosion of content: BEng students continued to learn the entire past curriculum in addition to the more basic topics, and although the content increased, student achievement improved. Handouts were provided for students; these proved to be especially helpful for the relatively high proportion of dyslexic students in the College. Similarly, various Statistics modules were also redesigned, with handouts provided and use of computers incorporated where appropriate. Mathematics support provision commenced in 2001 with the employment of a part-time Support Tutor, the author of this paper, at the same time as the curriculum changes were implemented.

Research into students' experiences learning mathematics and statistics was undertaken between 2004 and 2007. This was part of a wider study undertaken for a higher degree, which was supervised by Loughborough University. The aim of the research was to understand better the students' experiences and to provide a student 'voice', and questionnaires were administered by lecturers in Mathematics and Statistics modules: 245, 277 and 179 student questionnaires were completed in 2005, 2006 and 2007, respectively. Open and closed questions explored student qualifications, their experiences, confidence and attitudes as well as their use of the mathematics support. Overall, good response rates were achieved (e.g. 63%) and the resulting data, together with student module marks, was analysed using Excel, Genstat and SPSS computer packages.

Mathematics Support Provision

The mathematics support introduced at Harper Adams in 2001 through the appointment of a part-time Support Tutor was initially aimed at first-year Engineering Mathematics and first-year Statistics modules, to help overcome student difficulties and poor progression rates. The support has since been extended and developed, and is currently available for the following subject areas:

- First- and second-year Statistics and Engineering Mathematics;
- First-year Engineering Mechanics;
- Computer packages Excel, SPSS, Genstat and mathcad;
- Dissertation and research project analysis;
- Mathematical topics across College.

The support is available in a variety of ways, as listed below:

- Individual appointments booked in advance;
- Small group support for first-year Mathematics and Statistics modules;
- Workshops on specific topics e.g. elasticity in economics, drug calculations for veterinary nurses, valuations for surveyors;
- Larger drop-in sessions for revision and assignment support;
- Provision of support materials: e.g. **math**centre resources.

The mathematics support was found to be a value-added measure, being used by, and improving the performance of, students with lower mathematics qualifications. For example, comparing students with the same GCSE mathematics grade, it was found that supported students' performance improved by 3-4% in first-year Statistics.

The Student Experience

In the student questionnaires, mathematics support was rated positively with mean ratings consistently above 4 out of 5 and with many positive comments. It was frequently identified by students as a helpful feature. Below are some examples of comments made by Engineering students:

- *"Maths Support was very useful, without it I don't believe I would have passed this module, but now I'm getting 'A' grades"* (2003);
- *"Very Good overall"* (2005);
- *"The individual tutoring was a great help and I was very grateful for the help I received coming up to exams"* (2005);
- *"Made maths a lot more clear".*

Similar endorsement was provided by the statistics students:

- *"Very thorough and explained well"* (Surveying Student);
- *"Students definitely need her";*
- *"Great, friendly, helpful"* (Veterinary Nursing Student).

Attainment and Progression

First year Engineering students' mathematics examination marks were greatly improved after the introduction of mathematics support and curriculum changes. Figure 1 illustrates the increase in attainment for BEng, BSc and HND students from academic year 1999/2000 to academic years 2002/3 and 2003/4.

Improvements in attainment were recognised both by the College and by external examiners. For instance, Engineering external examiners for 2004, Professor R. McCafferty and A. A. Metianu, respectively commented:

> "*Particular efforts have been made to support students in the area of mathematics. This has resulted in significant improvement to student performance and an almost 100% progression rate."*

And

> *"There has been a marked improvement in the results … typified by … (HND group), where over 75% of the group achieved distinction level."*

Improved student performance has continued to date, with similar mean examination marks achieved by successive years. There has been good uptake of mathematics support, particularly by Engineering students. Indeed, in some years 50% of these students have used the support.

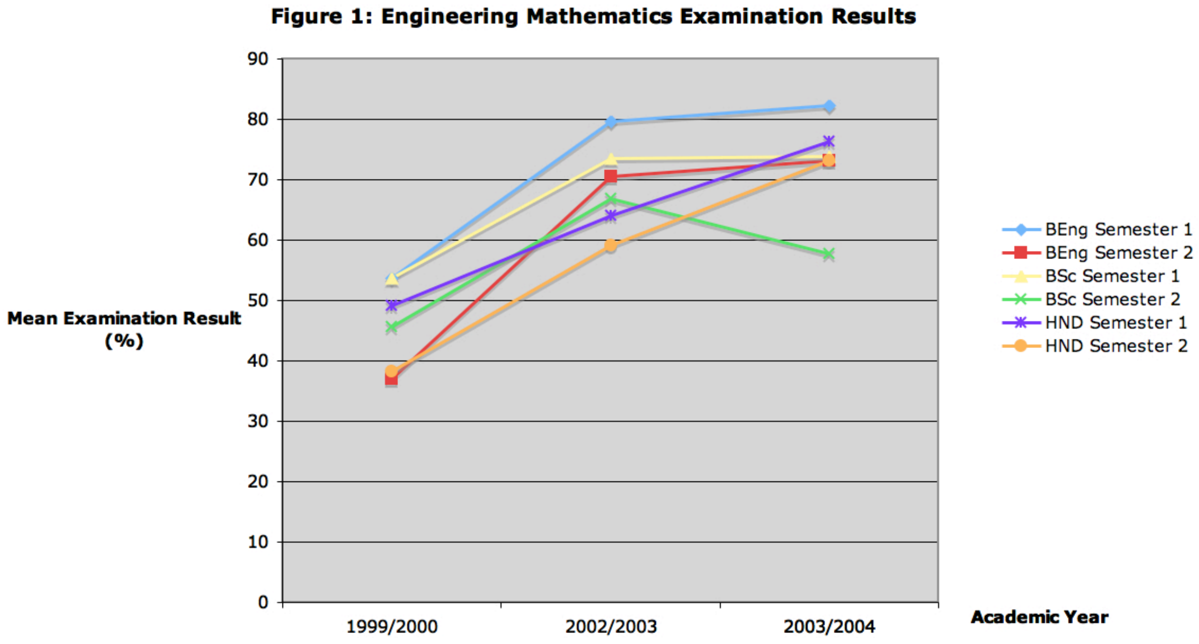

Figure 1: Engineering Mathematics Examination Results.

Discussion

Improvements in student retention and progression, not to mention improved student experiences, resulted from the curriculum changes and mathematics support (Parsons, 2005). In recognition, the mathematics support, first-year Engineering Mathematics modules and the 'Research Design and Analysis' module (a module teaching statistics and experiment design) all received Harper Adams Teaching Fellowship Awards in 2003 and 2004.

Clear relationships were found between students' mathematics qualifications before university and their performance at university. Relationships were also found between student confidence in these subjects and university performance. It should be noted that, whilst most aspects of the teaching and support were described positively, students' confidence and attitudes were sometimes still low, especially those learning Statistics.

Whilst the mathematics support provision has been shown to have had a positive effect on students' performance and experiences, there remain ongoing challenges to sustain and improve the service. There are peak times when the demand for support exceeds the availability, for example, when many students postpone seeking help until close to assignment deadlines and examinations dates. Moreover, close co-operation with lecturers is necessary to tailor the support to module content and assessment: changes in module content, teaching staff and computer software versions make this an ongoing task. Finally, each cohort of students needs encouragement to seek support and each year some of those most in need of support either don't seek help, or, due to avoidance of the subject (particularly statistics), put off seeking help until the last minute. There are no easy answers to these issues, and there is always room for improvement, but much has been achieved and continues to be achieved for the benefit of many students every year.

Conclusion

Harper Adams students were recognised to have a quantitative skills gap, in response to which part-time mathematics support was introduced in 2001, alongside curriculum changes. Many hundreds of students have benefited from the support with recognised improvements in student achievement. The support has received positive feedback and high ratings, both from research into student learning of mathematics and statistics and through central college student feedback. Ongoing challenges exist to provide the support, but overall the investment in mathematics support over seven years has been worthwhile both in terms of improved student experience and improved retention and performance.

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Acknowledgements

My grateful thanks go to my research supervisors: Prof. Tony Croft and Dr. Martin Harrison, at Loughborough University Mathematics Education Centre, and to Harper Adams University College Aspire CETL for a Development Fellowship Award, which funded part of the research work.

Development of Computer-Aided Assessment of Mathematics for First-Year Economics students

M. Greenhow

Abstract

This paper reviews the background for the Mathletics database of questions and describes its extension to computer-aided assessment provision of elementary mathematics tests for first-year Economics (and economics-related) students. Various design issues are described and the important idea of a question style (as opposed to a realisation of that style) is explained, both from the technical and pedagogic point of view. These ideas are illustrated by giving screen shots of questions realisations in the Economics context, and some remarks are given about their use with students at Brunel University.

Introduction

Over the last six years, the Computer-Aided Assessment (CAA) team at Brunel University's Department of Mathematical Sciences (a team led by Martin Greenhow, comprising a number of postgraduate students as well as undergraduate students taking on a final-year project in CAA) has been developing the Mathletics database of questions. Comprising some 1800 question *styles*, the database spans much of the A-Level syllabus for mathematics modules C1-C4, S1 and M1, as well as substantial material at GCSE, Higher and first-year university level; some advanced calculus question sets have also been developed in such areas as Laplace and Fourier transforms, Fourier series and ordinary differential equations. At this more advanced level, pedagogic issues arise which limit the feasibility of setting objective questions in any CAA system, or even on paper (see Baruah and Greenhow, 2007). However, at the boundary of school and university, the usefulness of CAA, and Mathletics in particular, is reasonably well established and provides a useful and popular addition to the blend of assessment methods (see Gill and Greenhow, 2007). Whilst that paper uses a first-year Mechanics module as its case study, many of the lessons learned are believed to be widely applicable in other areas of mathematics and beyond. Major points include the need for:

- Question metadata encapsulating the algebraic and pedagogic structure of the question style (see below), so that the database can be sensibly ordered and assessments created easily;
- An underlying taxonomy of errors to provide outcome metadata so that the (hundreds of) answer files may be ordered and understood in a way that infers the nature of the students' incorrect thinking;
- Extensive feedback (which is used as a learning resource in its own right) - see especially Figure 3 (students have been seen to spend most of their test time studying this feedback, often responding randomly simply to gain access to the feedback);
- Full incorporation of the tests into the overall curriculum (typically this means that scheduled and staffed PC-Lab sessions are timetabled and that marks count towards the module total in some, usually small, way).

At present approximately 10 modules at foundation, first- and second-year levels are using the system. About 400 students have (thousands of) answer files recorded for marks, whilst a similar number make informal use of the database (without recording marks) mainly as a learning resource. Students in each category are using both decontextualised material, such as that in A-Level Mathematics, as well as the newly-developed domain-specific economics-related questions from the FDTL5 'METAL' project that forms the content of this paper.

To understand how the database works it is necessary to appreciate what lies behind the creation of the examples illustrated in Figures 1-3, shown below. These examples are actually question *realisations*, as seen by the student, which are generated at runtime using Javascript coding within Question*mark* Perception's open-scripting capability (unfortunately not available in Perception version 4). The scripting modifies that of existing question *types* (multiple choice, numerical input, etc.) and encodes the *style* (essentially a template) of the question, allowing random parameters to be chosen to give thousands or millions of realisations. Thus, each question is coded algebraically, the correct answer given by the usual mathematical procedures, and distracters given by making and following through the consequences of mistakes commonly made by students. Such 'mal-rules' may be evidence-based (found by examining past exam scripts or other student work) or lecturer-based (those anticipated by an experienced teacher). One needs then to record the essence of the mal-rule in some sort of metadata that is written to the answer files, see Table 1 taken from Gill and Greenhow (2007). One also needs to ensure that, for the allowed random parameters, the resulting correct answer and all distracters are unique (for example, distracters based on squaring a number or doubling a number will yield the same result if that number is 2, which therefore must not lie within the range of allowable values).

It is important that random parameters are carried through to all elements of the question and its feedback, including equations and diagrams. This is done by inserting the values of the parameters at runtime into plain-text strings; MathML is used for mathematical display, whilst diagrams are generated via Scalable Vector Graphics (SVG). An unlooked-for, but welcome, consequence is that an accessibility feature (by clicking Fonts & Colours at the top right of the screen, as illustrated in Figure 1), allows students to alter the appearance of all question/feedback elements, so that partially-sighted students choosing a large font will also see large equations and large diagrams. Similarly, selected colour schemes can be helpful to certain dyslexic students.

Underlying the questions are sets of functions, held centrally and included in the question as required by selecting the so-called "question templates" when designing the assessment. These functions divide into two classes; those that do mathematics (e.g. return the value of a determinant) and those that display either mathematics or diagrams by returning MathML or SVG strings respectively.

Examples of Question Realisations

We consider first a decontextualised question in basic algebra. Figure 1 illustrates a snapshot of the feedback screen for such a question. The print and accessibility options are shown, followed by a restatement of the question and a results section. A "Related material" button calls a function that reads the question topic, finds it in a centrally-held (and therefore easily maintainable) array and returns relevant links to web-based material, such

Error Type	Classification
Assumption	Students assume certain things that are not true, for example, in projectile questions, that vertical veloc ity is equal to initial velocity.
Calculation	Method correct but calculation errors are made.
Copying	Copying values incorrectly.
Definition	Not knowing the definition of terms given in question text, e.g. magnitude.
Formulas	Incorrectly statin g/recalling formulas.
Incorrect Values Used	Using incorrect values in method, for example, when substituting values into formulas.
Knowledge	Knowledge students are lacking that would enable them to answer questions.
Methodology	Students attempt to us e an incorrect method to answer a question.
Modelling	Generic definition, e.g. ignoring forces , such as gravity, acting on particles.
Procedural	Method student attempts to use is correct but can only do initial/certain stages of the method. They stop ha lfway through when they do not know the stages that follow or when they are unable to interpret initial results.
Reading	Reading the question text incorrectly and confusing the value of variables.
Trigonometry	Basic definitions of cosine, sine an d tan incorrect. This is most apparent in questions where students are required to resolve forces.

Table 1. Classification of errors according to an underlying error taxonomy (from Gill and Greenhow (2007)).

as that from **math**centre or, in the present case and in the near future, the Economics videos developed by Portsmouth University as part of the METAL project.

Here the random parameters (-27, 37, 7 etc) are given by the question metadata

y=Cx^2+(E-CA-CB)x+(CAB+F); y=Ex+F; roots=A,B; 2NI

showing that both solutions of a quadratic and a linear equation are required, but with coefficients that are reverse engineered to ensure the roots are integers. This is a 5-parameter question, resulting in around 3 million realisations assuming parameters can range over 20 choices. At the level of this question, the feedback is quite brief in that solution of a quadratic by factorisation is an assumed skill; students lacking such skills can click the 'Related material' button to open the window with links to external URLs as shown.

The question realisation illustrated in Figure 2 is essentially a clone of that illustrated in Figure 1 except that it is set in an economics context and shown with a different colour scheme. Note that, given the contextualised nature of the question, a comment regarding the applicability of the solutions obtained from solving the simultaneous equations is required.

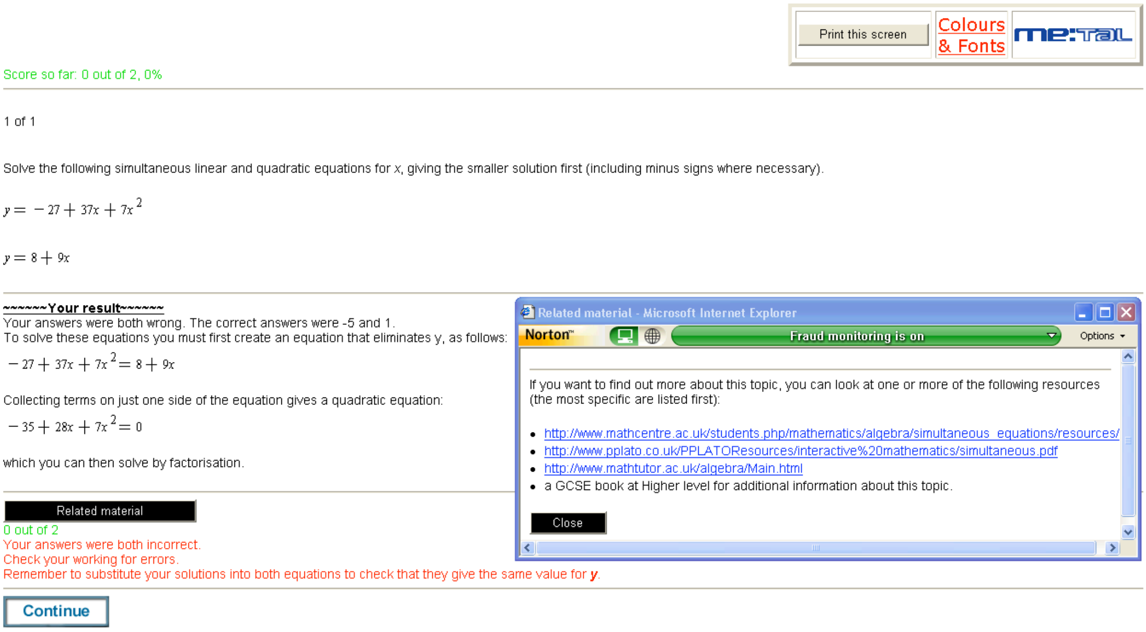

Figure 1. Feedback screen for a decontextualised question about simultaneous equations.

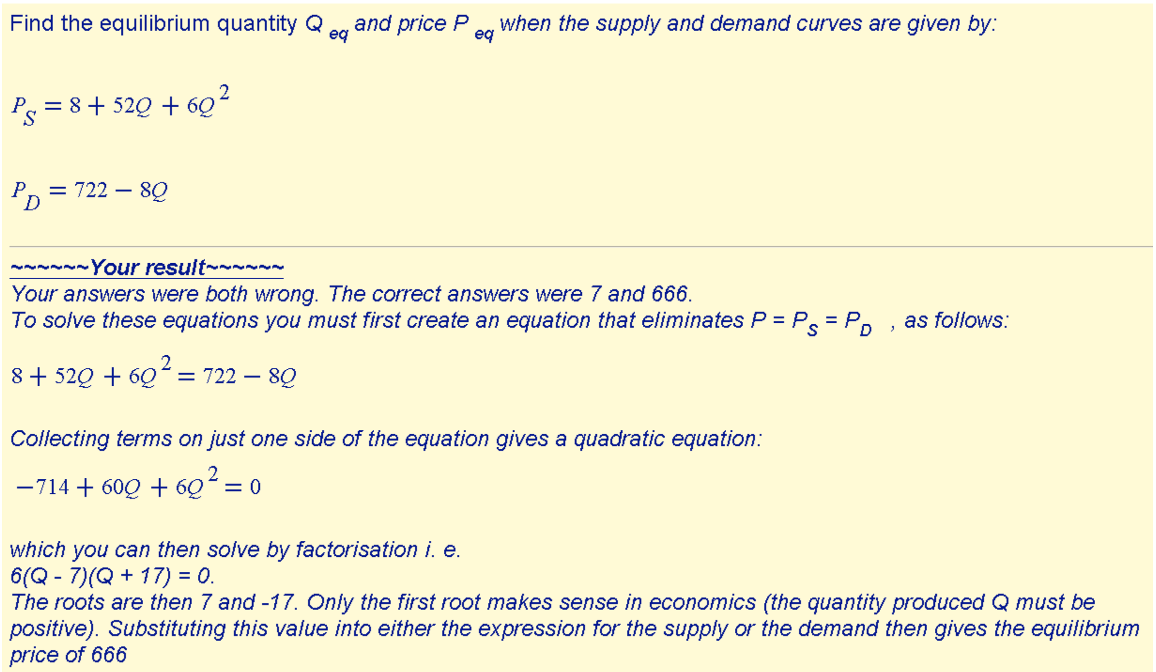

Figure 2. Feedback screen for a contextual question about supply and demand equilibria.

Our third example, illustrated in Figure 3, is both contexualised and graphical. It shows a linear programming question with metadata "given scenario find optimum X position (no degeneracy), region IV; 2NI".

This question presupposes fluency with the equation of a straight line and solution of simultaneous equations, similar to those above. Note that the coding of the question style not only randomises the numbers and currencies involved, but also randomises the context or *scenario*, referring to, for instance:

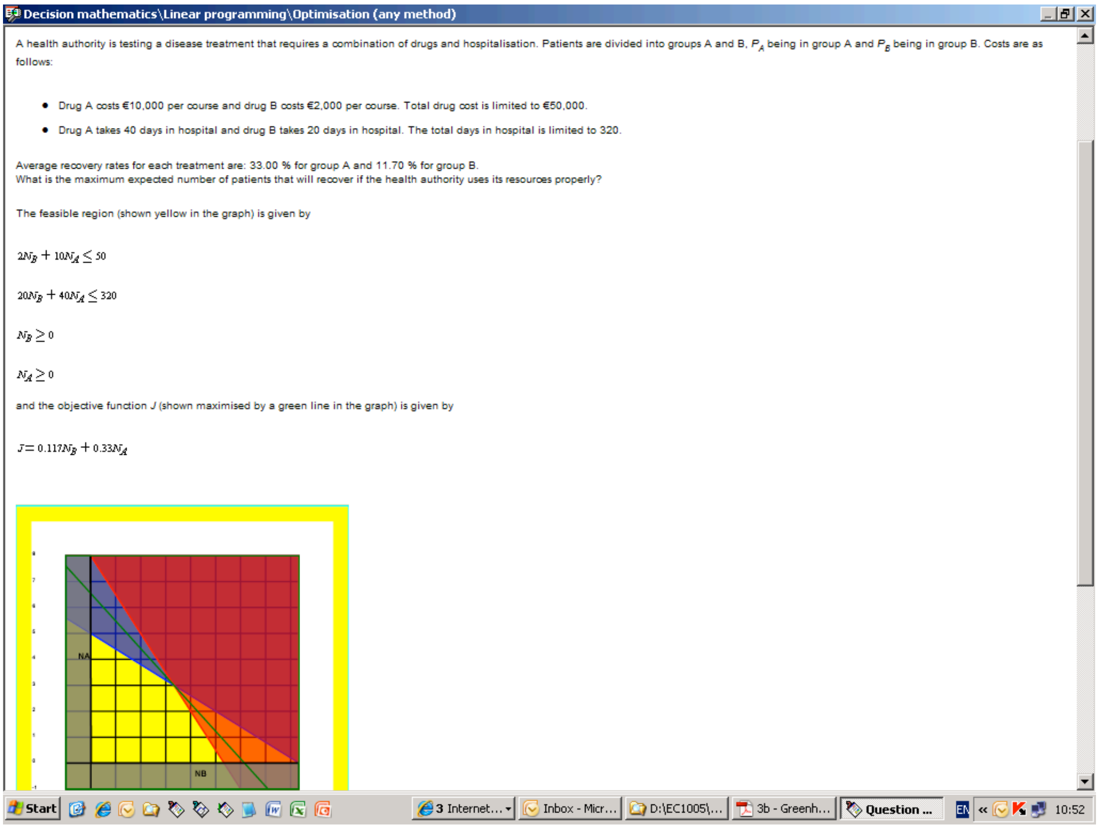

Figure 3. Part of a feedback screen for a linear programming question.

- A health authority (as shown), optimising the number of recoveries;
- A city trader or an electronics company, optimising profit;
- A zoo, optimising visitor hours; or
- A tobacco company, optimising addiction rates (!).

Although superficially different, it is hoped that after sufficient attempts, students will realise that the solution of all the questions is the same or similar, i.e. they will have mastered the techniques of linear programming for use in any situation. The feedback screen restates the problem in words, formulates it mathematically, and portrays it graphically just as a teacher would in class. Note that the feasible region is bounded by possible optimal points that are guaranteed to be integers (whole numbers of patients, etc) by reverse engineering the question accordingly.

Observations

It is natural and important to ask how effective these computer generated tests and (where necessary) accompanying explanations are in terms of improving students' understanding of the material and hence improving their examination marks. For the Economics questions shown here, we do not yet know at this early stage in the project. However, studies over six years for Mechanics CAA reported by Gill and Greenhow (2007) show statistically significant and beneficial effects.

A second important and related question is how do students perceive the CAA? Here, the answer is that they are overwhelmingly well received. It should be noted that there is (justifiable) hostility to questions that are not robust with certain parameter choices but that this is very difficult to avoid at the authoring stage, and extensive trialling seems necessary to detect all such weaknesses. Nevertheless, the fact that students engage with the CAA enthusiastically is in stark contrast to other forms of assessment, or even teaching. The following student quote expresses many widely held views:

> *"I personally prefer the computer-based-assessments as you don't feel the intensity of exams and you can work according to your own speed. Also, you know immediately after completing the question whether or not you got it right so there's no anxiety in comparison to results day. It also helps with understanding where you went wrong so you can rectify your mistakes with the following attempts as you can print screen the questions you answered incorrectly ... and it's really useful for people with different learning styles and dyslexic folks who don't necessarily like formal scenarios like exams under timed conditions."*

Conclusions

The METAL project has resulted in a useful and popular addition to the blend of assessment methods used at Brunel University. The assessments have been disseminated widely in UK Economics departments. Much useful, and generally positive, feedback has been obtained from academics at other universities, most of which has been incorporated into the existing version. It is therefore expected that other universities will utilise the assessments. For now, extensive testing with students at Brunel University over the last 3 years leads us to believe that:

- Testing mathematically-based material at the school/university interface via CAA is feasible from a technical and pedagogic viewpoint;
- Mal-rules may be applied in other areas of mathematics and beyond;
- An error taxonomy can be applied in other areas of mathematics and beyond;
- CAA is a popular resource; and
- CAA is effective in the learning process if full feedback is given and students spend the time to engage with it.

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Acknowledgements

This work was supported by the FDTL5 "Mathematics for Economists; enhancing Teaching and Learning (Metal)" Project carried out by Nottingham Trent University (lead site and study guides), Portsmouth University (videos and flash animations) and Brunel University (CAA).

School Mathematics and University Outcomes

M. Houston & R. Rimmer

Abstract

There is concern that, as participation of non-traditional entrants widens, many university graduates do not have the mathematical skills vital for professional work. The purpose of this paper is to examine the relationship between mathematical attainment at secondary school and the outcomes of university study in quantitative disciplines. In particular it considers progression through the years whilst at university.

An 'engagement' theory of higher-education study is used to investigate academic performance and progression among students in a university that has embraced widening participation. The study is restricted to those who gained entry via Scottish Higher examinations. Within this environment there is considerable diversity. For example, although most students were 18 on entry, students' ages ranged from 16 to 38. In addition, while pre-entry preparation in mathematics was not extensive, this varied. At the university, assistance with mathematical skills is embedded in programmes and is discipline specific.

We observe that, in general, students with better pre-entry attainments in mathematics had better average marks, maintained greater study loads and were more likely to progress. However, non-traditional female students with poorer mathematical backgrounds were able to attain comparable outcomes.

Introduction

In *Measuring the Mathematics Problem* (Hawkes and Savage, 2000), a report published under the combined auspices of the MSOR Network, the Institute of Mathematics and its Applications, The London Mathematical Society and the Engineering Council, Hawkes and Savage concluded that there is a decline in

> *"mastery of basic mathematical skills and levels of preparation for mathematics-based degrees". Further, "the decline in skills and the increased variability within intakes are causing acute problems for those teaching mathematics-based modules across the full range of universities".*

This decline has been associated with the drive to widen participation in Higher Education which has increased participation among those over 21 as well as those from disadvantaged socio-economic groups and those from postcodes where the proportion in Higher Education is low (Randall 2005; Houston, Knox & Rimmer, 2007).

While those charged with lecturing mathematics-based content are in little doubt about declining mathematical skills among entrants and the need to accommodate this in day-to-day teaching, the implications for quantitative skills of graduating students is not so clear. Indeed, research into changes in the proportions of good degrees (firsts and upper seconds) over a five-year period in the 1990s (Yorke, 2002) implied that the mathematical sciences was one in which an upward drift was apparent across the whole university sector. Simonite (2003) associated this upward drift with increasingly better grades at school.

Using data from two universities, researchers have formulated and tested an engagement model of Higher Education study that links academic performance, study effort, and progression (Houston & Rimmer 2005; Houston, et al. 2007; Donnelly, McCormack & Rimmer 2007). In this paper we consider entrants admitted in 2000 on the basis of Scottish Higher examinations to the University of the West of Scotland (UWS). We use available data on the 276 students who enrolled in first-level 'quantitative' programmes, that is programmes in which the normal full-time load involved the study of more than four modules with quantitative or scientific elements. Based on the data for this cohort of students, links between school mathematics and university outcomes can be investigated in a population which exceeds benchmarks on widening participation.

Method

The adopted approach is underpinned by the following observations:

- Students choose or decide how much effort to apply to their studies;
- In general, grades improve with effort (Szafran, 2001);
- Better grades in turn induce increased effort; and
- Greater effort increases the probability of progression (Houston & Rimmer 2005; Houston et al., 2007).

The main factors considered in this paper are school performance, university study load, level of attainment at university and progression onto higher levels. School performance is measured by attainment in Scottish Highers, awarded as letter grades A, B, or C but, for the purpose of this research, converted to numeric scores via the mapping $A \rightarrow 3$, $B \rightarrow 2$ and $C \rightarrow 1$. To obtain an overall Higher score, the best three were summed. This is 'score over best three subjects' in Table 1. Restricting attention to three is consistent with research elsewhere (Houston et al., 2007).

With UWS data, effort was observed in the form of 'load', that is the number of modules in which at least one assessment was attempted. Progression is defined as being re-enrolled in the next level of study one month after the commencement of the next academic session; obviously, some students failed to satisfy progression rules, however, additionally, many students at UWS who could have progressed chose not to do so (Houston et al., 2007).

Table 1 below illustrates that although the majority of students are white, in all other respects (from age range to load or number of modules attempted, by gender and by attainment in Highers) the population is very diverse.

Attainment in Mathematics Higher can be broken down further. In particular, 40.9% of the 276 students had not passed Mathematics Higher, 38.4% had passed at Grade C, 18.8% had passed at Grade B whilst only 1.8% had passed at grade A.

Age:	**Mean**	**Standard Deviation**	**Range**
	18.3	2.5	16 to 38
Ethnic Origin:	**White**	**Non-white**	
	92.8%	7.2%	
Score in Highers (where A=3, B=2, C=1, None=0):	**Mean**	**Standard Deviation**	**Range**
Score over best three subjects	4.4	1.6	1 to 9
Score in non-quantitative subjects	2.7	1.7	0 to 8
Score in Mathematics	0.81	0.80	0 to 3
School of enrolment:	**UWS Business School**	**Communication, Engineering & Science**	**Education & Media**
	21.4%	77.9%	0.7%
University Attainment:	**Mean**	**Standard Deviation**	**Range**
Load	7.5	1.4	1 to 8
Mean mark	53.0	13.5	4.0 to 81.0
Progression to next level:	**Progressed**	**Didn't progress**	
	75.7%	24.3%	
N = 276			

Table 1. Summary statistics for students enrolled in first-level quantitative programmes at the University of the West of Scotland in 2000/1

Results

In this section we discuss the impact of personal and institutional factors as well as attainment in Highers on university attainment, progression and load. First it is of interest to investigate the relationships between those personal and institutional factors and attainment in Highers in both quantitative and non-quantitative subjects and indeed the relationship between attainment in Highers in quantitative and non-quantitative subjects. It should be noted that there was little correlation (p = 0.307) between overall Higher score excluding Mathematics and Higher score in Mathematics. That there was a high correlation (p = 0.000) between overall Higher score excluding Mathematics and Higher score in non-quantitative subjects was of little surprise since many of the students did not have science or other quantitative subjects among their best three. Gender had a strong influence on both non-quantitative and Mathematics score (p = 0.001 in both cases) and age had a slight influence on non-quantitative score (p = 0.086).

Some interesting observations were made whilst exploring the influence of personal factors on load, performance and progression. It was noted that age and gender both influence load (p = 0.003 and p = 0.088) whilst neither has a significant effect on progression (p = 0.291 and p = 0.249). Being white had little influence on load and performance but did affect progression (p = 0.007). The only institutional factor taken into consideration was faculty of enrolment. It was found that students from the UWS Business School (UWSBS) taking quantitative modules (Accounting, Economics, Finance or Land Management) typically underperformed relative to their counterparts in the schools of Communications, Engineering and Science (CES) and Education and Media (E&M).

By taking a comparator group (18 year-old white male students who had achieved a score of 6 in their Highers including a B in Mathematics and who were enrolled in CES or E&M) and comparing it to other groups that differ on just one pre-entry characteristic, Table 2 below exposes the impact of personal and institutional factors on performance, attainment and progress.

	Mean Load	**Mean Outcome** (%)	**Progression Rate** (%)
Comparator group [1]	7.7	57.4	91
Comparator group except:			
• No Higher in mathematics	7.6	53.7	73
• Mathematics Higher grade of C	7.7	55.5	85
• Mathematics Higher grade of A	7.7	59.2	94
• Female	7.8	60.8	96
• Not white	7.7	57.3	68
• Aged 25	7.9	61.8	97
• Enrolled in UWSBS	7.6	52.3	84
White female, aged 18, Higher score = 6 with:			
• No Higher in mathematics	7.7	57.2	91
• Mathematics Higher grade of C	7.8	59.0	93

[1] The comparator group consists of 18 year old, white males, who entered with a Higher score of 6, including a B in mathematics, and who were enrolled in CES or E&M.

Table 2. Load, average mark and progression for groups of first-year entrants enrolled at the University of the West of Scotland in 2000/01

Four things are notable:

- First, women with the same school Mathematics achievement attain higher average marks and are more likely to progress in the study of quantitative programmes;

- Second, non-white students take the same loads as comparable white students, have about the same average mark, but have substantially lower progression probability. This demonstrates that progression does not depend solely on academic performance (Houston et al., 2007);
- Third, older students attempt greater loads, have better average marks and are more likely to progress than students in the comparator group;
- Finally, students studying quantitative programmes in the Business School are at a disadvantage, even though they have the same Higher grade of B in Mathematics. One explanation of this is that assessment standards are more severe in UWSBS than in other schools. This is consistent with other evidence (Yorke 2002; Houston et al., 2007). However, in addition it may be that different teaching and learning cultures pervade university schools, and hence deficiencies in mathematical skills are handled differently between disciplines.

At the bottom of Table 2, two rows of outcomes are shown for women with low attainments in Higher Mathematics. This illustrates that women with no Higher Mathematics or a grade of C, attain average marks and progression rates that are about the same as, or exceed those of, males who had a Higher Mathematics grade of B. Thus in the case of females, poorer mathematics preparation has not severely constrained university performance. It is possible that the efforts women exert once at university lead to substantial pay-offs, including overcoming any shortcomings in mathematical background.

Conclusion

The aim of this paper was to examine the role of school mathematics in university outcomes at an institution that has widened participation, emphasising the loads full-time students choose to study, their average marks in quantitative programmes and whether they progress from first- to second-level at the earliest opportunity. The approach involved a model of student engagement and the precedent in earlier research of using best-three school results. This allowed us to conclude that the findings are in line with earlier research.

Within this context, it emerged that non-traditional entrants to quantitative programmes, notably women, can overcome weaker preparations in school mathematics to perform creditably in quantitative programmes. Further, provided engagement with study is strong, in the form of attempting near full loads, students are on pathways to enrolling again next session in the second level of their programmes. A notable exception to this is students who were classed as non-white in the research.

In the case of older Higher entrants, their experiences, after first leaving school and before doing Highers, may have further equipped them for quantitative programmes. This might go some way to explaining outcomes for those non-traditional UWS entrants who were over 21. Even if the finding of the current research on older students is associated with non-school experience, this does not invalidate the conclusion that many types of entrants to a widening-participation institution can succeed. Moreover, one purpose of widening participation is to provide opportunities to those who traditionally have not attended university. That some ultimately arrive with relevant experience reinforces the notion that alternative entry routes – other than arriving at university immediately after a single episode of schooling – are valid. It should be noted that external examiners at UWS have not suggested that academic standards are compromised by allowing students with poor preparations in mathematics to pass and progress; in fact the reverse is the case, with externals remarking that standards are high.

It is hoped that the approach of this paper is applied in other settings to explore the importance of pre-entry mathematics. Clearly, at institutions where school mathematics results are less modest and the incidence of studying other quantitative or science subjects is more widespread than at UWS, the findings may be different.

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Employability Skills: A Key Role for Mathematics

S. Hibberd

Abstract

The importance of a sustained supply of highly skilled graduates is increasingly recognised by the UK Government as a key factor in maintaining the country's position as a leading knowledge-based economy. However, whilst a wide range of employers continue to emphasise the importance of strong numerical, analytical and problem-solving capabilities in graduates, they also highlight an ongoing 'employability skills gap'. This paper examines the current state of quantitative studies and highlights the gains for students that may arise from a mathematics experience that includes wider skills and competencies.

Introduction

Following several influential Treasury-commissioned reports, including Roberts (2002) and Leitch (2006), it is widely accepted by both Government and employers that, if the UK is to maintain its status as a leading knowledge-based economy and to reap the rewards that may accrue from that status, a supply of highly skilled graduates that is both sustained and sustainable is vital. The four strategic STEM subjects are identified as being particularly important. Indeed a strategic report by the Higher Education Funding Council for England (HEFCE, 2005) identifies mathematics as a uniquely pivotal subject because a decline in the supply of mathematicians and those skilled in quantitative techniques would have a significant impact on many other subjects.

The report identifies a subject as vulnerable if there is a possible mismatch between supply and demand at either of the following key transition stages: first, to Higher Education from school or college, and, second, from Higher Education to employment. This is illustrated in Figure 1.

Supply of potential students for Higher Education

↓

Higher Education provision to the nation
(Whether of skills, business, or community activities, or of research)

↓

Employer, Government or 'other' (e.g. cultural) demand
(Whether current or predicted)

Figure 1. Identification of key transition stages for students in Higher Education.

The gap between mathematical competencies acquired at school/college and the level of preparedness either expected or required on entry to degree courses that contain a significant quantitative component has become known as 'the mathematics problem' (Savage, 2003). Measures taken by HEFCE to address the mathematics problem include making available significant funding through CETL initiatives and through the Fund for the Development of Teaching and Learning (FDTL). However, whilst initiatives designed to increase the supply of students into Mathematics, or mathematics-related subjects at university are welcome, we observe from Figure 1 that in order for the UK to obtain the full benefit, these skills must filter through to the workplace.

The second key transition stage, that from student to employee, is increasingly becoming a priority and an ongoing 'employability skills gap' has been highlighted. It is unsurprising that both Government and a wide range of employers regularly and repeatedly emphasise the importance of strong quantitative capabilities in graduates. Moreover, whilst regrettable, given the concerns about quantitative skills both at the school and university levels, it is equally unsurprising that employers raise concerns about a lack of relevant transferable and generic skills amongst employees. However, more recently these concerns are being echoed by the students themselves: an increase in awareness of personal financial investment in Higher Education is leading to a corresponding increase in career aspiration upon graduation.

Thus, there is a growing demand from all quarters to recognise and integrate into degree courses, and specifically into Mathematics degrees or other degrees with a significant quantitative component, skills perceived as widely applicable throughout industry, business and commerce, and in both the public and private sectors. With additional Government-backed initiatives (see e.g. Grove, 2005), pressure is increasingly being exerted on universities to place greater emphasis on employability considerations. Aspects of the employability skills gap are considered in (Hibberd, 2006), which promotes greater development of skills, attributes and attitudes, and which encourages Higher Education institutions to prioritise increased interaction with employers and to promote increased skills acquisition amongst their graduates.

Mathematics and the Employers' Perspective

Learning in the 21st Century is characterised by rapid change, a surfeit of information sources, globalisation, new technologies, and new ways in which graduates work, study and live. As a result there is growing recognition that universities need to help students cope with complexity and change. In a recent statement, the Minister of State for Lifelong Learning, Further and Higher Education (2005) observed that:

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

emphasising an increased expectation from Government that university Mathematics courses should prepare their graduates to work in the wide range of sectors that require strong numerical skills. The revised Benchmark Statement for MSOR (QAA Subject Benchmark, 2007) remains upbeat on the topic of career opportunities for mathematics graduates and identifies relevant careers websites sponsored by the MSOR professional bodies. However, such optimism may not be readily justifiable in all programmes or for a comprehensive range of skills if we examine responses to the annual National Student Surveys (NSS).

A national project on Student Employability Profiles (Forbes & Kubler, 2004/5) was commissioned by the Higher Education Academy (HEA) and the Council for Industry and Higher Education (CIHE), supported by the Quality Assurance Agency for Higher Education

(QAA). It identified for employers a set of competencies that might be expected of graduate students as follows:

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

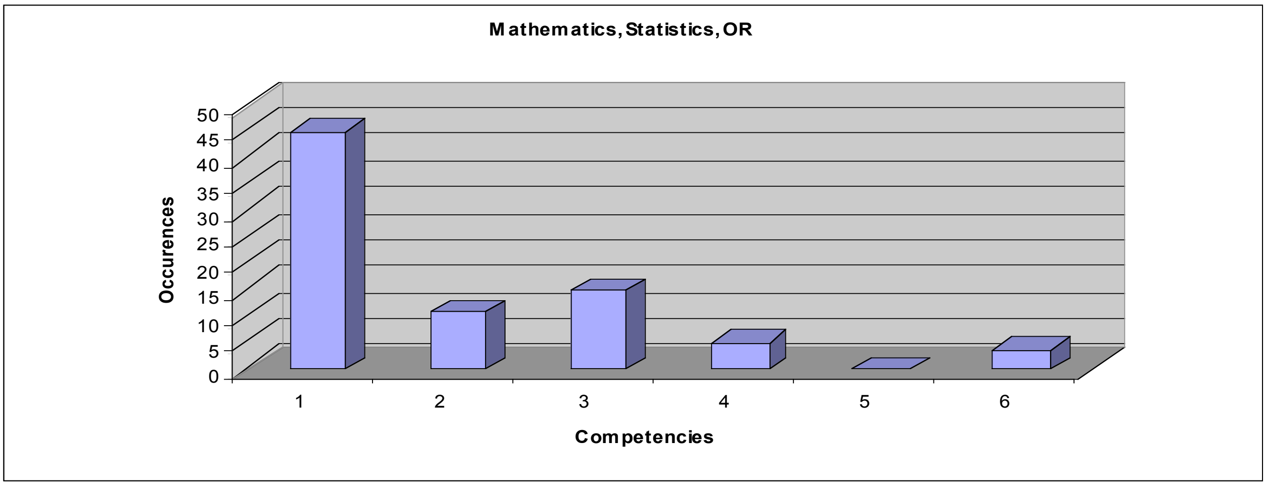

Figure 2. Frequency of reference for each of the six competencies within the profile of a Mathematics, Statistics or Operational Research Graduate.

Even a cursory inspection of the balance of competencies typical of students within the domain of MSOR, as illustrated in Figure 2, reveals an overwhelming emphasis on cognitive skills with limited reference to the remaining competencies. This skew is particularly apparent when compared to the competencies identified for other Science and Engineering subject groups.

To facilitate future strategic decisions, the Royal Society has commissioned a project to consider:

> "*Whether the overall STM HE provision in the UK will be fit for purpose by the second half of the next decade.*"

Following a call for evidence, initial responses were provided via the MSOR Network (Hibberd & Grove, 2006), professional bodies and others. A subsequent Phase 1 report (Royal Society, 2006) sets out background information and initial findings of the project. They write:

> "*Our report is intended to provide a reliable foundation for further work on aspects of HE policy and we hope that those concerned about HE whatever perspective will find it of value. The analysis has highlighted several unresolved issues …".*

These issues include an evaluation of the benefit that students get from studying STM subjects at tertiary level, and highlight the importance of quantitative skills.

Mathematics and the Students' Perspective

An extended National Student Survey (HERO, 2007) has been operational since 2005 to provide data based on questionnaires circulated to students in their final year of study. Average scores, by institution and by Subject Centre, to questions covering six categories (teaching, assessment and feedback, academic support, organisation and management, learning resources, and personal development) are available in the public domain. Of particular note with respect to employability skills is the response to the category 'personal development', based on 3 questions:

- The course has helped me to present myself with confidence;
- My communication skills have improved;
- I feel confident in tackling unfamiliar problems.

With possible responses ranging from 1 (strongly disagree) to 5 (strongly agree), the combined average score for MSOR in 2005 was 3.7. This was the lowest score for this set of questions across all subject centres, and was corroborated by a similar score in 2006. Some representative student comments included:

- "*Very little emphasis was put on presentation, communication or group working skills, which are particularly disappointing on a 4-year course at such a respected university. This meant interview situations were more unnerving than they should have been with prospective employers, and also very little opportunity to use university work as examples*."

- "*The course has been very interesting, though its not always obvious how much of what we learn could be used in real life situations (which is of course what I believe to be most relevant).*"

In a recent study on the career paths of graduates with degrees in mathematics or statistics (Huddlestone et al., 2007) based on detailed investigation from six employability case studies,

> *"it became clear that the two most important aspects for a successful applicant were to satisfy the academic requirements and to plainly demonstrate the skills and abilities which the organisations were seeking."*

Closing the Skills Gap?

We have observed that there is a strong case for identifying, articulating and recording core skills, both general and subject-specific, that might be developed through the learning of mathematics. A telling comment regarding employability given in (Huddlestone et al., 2007) states:

> *"…it seems that firms are becoming increasingly reliant upon graduates having particular sets of competencies as well as academic qualifications. Consequently*

universities need to be mindful of this in terms of career advice and the preparation of undergraduate programmes."

The subject area of MSOR is a very broad grouping of traditional subjects and less traditional subjects (those categorised as 'theory-based' and those categorised as 'practice-based' programmes) although most courses include elements of both. As all branches of the subject area have a strong emphasis on problem solving and intellectual rigour as well as a strong numerical skills base, it seems likely that any attempt to move towards a greater 'employability' agenda will be approached with caution and possibly great scepticism.

However, as indicated earlier in this paper, there is a perception amongst employers that these traditional skills alone (problem solving, intellectual rigour, etc) will not satisfy future economic needs, nor do they fully meet graduate student expectations. We argue, therefore, that a '"complementary skills"' agenda within the curriculum could help facilitate MSOR graduates achieving higher employment outcomes. Ironically, time spent developing these complementary skills might lead to more effective learning thereby yielding students greater success in their studies and making them better prepared for postgraduate work. Examples of such complementary skills might include:

- *Communication Skill*s – the ability to express ideas clearly, convincingly and concisely, whether by oral or written formats;
- *Problem-Solving Skills* – the facility to embrace new ideas and, where necessary, to develop these ideas producing innovative alternatives;
- *Task Management* – the ability to adopt an organised and structured approach to solving a problem and to manage and prioritise multiple tasks;
- *Personal Effectiveness* – being self-motivated and having the ability to react positively to new challenges;
- *Team Working* – the facility to co-operate with others in terms of learning, developing and achieving.

Any effective change in agenda requires a sharing of responsibilities at global and local levels within the Higher Education community, and there are indications that institutions are becoming more receptive to the employability agenda. Increasingly they require that:

- Skills are more clearly and realistically identified in modules;
- Personal Evidence Portfolios, that is a record/transcript of individual student experiences and skills attainment, are produced;
- There is recognition of wider skills attainment within programme specifications;
- There is greater emphasis on NSS and other indicators of student satisfaction.

At the School / Department level, Programme reviews provide opportunities to initiate and incorporate structures that facilitate the development of skills within mathematics modules / courses. These include:

- Project activities;
- Integration of group activities;
- Professional experience and/or more vocationally orientated modules (e.g. student ambassador schemes);
- Study abroad opportunities.

Additionally, students may benefit from cross-curricula exposure. For instance, in 2003/4 over 40% of mathematics graduates went on to be employed in the business and finance sectors. These students might have benefited from the opportunity to study modules in these areas. Professional experience can be gained through work experience or internships.

Students taking subjects outside the scope of MSOR are often surprised at the quantity and level of mathematics (including statistics and numeracy) that they are required to undertake in order to complete their studies. This element of surprise arises largely because the mathematics content often masquerades under labels such as ‘quantitative methods’, ‘econometrics’, ‘research methods’, ‘data analysis’, ‘informatics’ and ‘professional practice’. On the positive side, for subjects such as Business, Economics, Psychology, IT and Nursing, the fact that the mathematics is so firmly embedded in context can make it much more accessible.

The traditional mathematics-rich subjects of Engineering, Physics, Chemistry (and increasingly Biosciences) where mathematics is often regarded as a “service subject” can learn from these subjects and can greatly complement their main areas of study if they:

- Recognise and cater for a wide range of mathematics backgrounds and initial abilities;
- Increase student confidence in using and understanding mathematical techniques;
- Ensure that the mathematics component is seen to be relevant to the subject;
- Maintain interaction with subject specialists;
- Meet professional requirements;
- Develop explicitly quantitative skills.

In particular, the development of relevant quantitative skills together with techniques have much to gain from increasing collaboration between mathematicians and subject specialists.

Discussion

There is increasing recognition from both Government and employers that, if the UK is to continue to compete on the global stage, degree specifications for subjects with a high mathematical component should address the acquisition of an extended range of subject-specific and wider skills. This recognition coincides with increased pressure from students, who see Higher Education as an investment in their futures, to enhance their employability prospects. University Mathematics departments are in a strong and strategically important position to help the UK to maintain a leading economy and to continue to attract students from overseas to study. However, seemingly conflicting requirements ranging from addressing the lack of fluency in basic mathematical skills displayed by many entrants, to the provision of specialist mathematics graduates to maintain the university research base, make this a difficult path to tread.

As an academic community, there is an ongoing need to recognise and integrate the skills that are, and could be, developed during the learning process within the study of mathematical and statistical elements.

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CHAPTER FOUR

The Future of Mathematics Support

A Problem-Based Learning Approach to Mathematics Support?

D. J. Raine, T. Barker, P. Abel & S. L. Symons

Abstract

This paper describes a 'resource-based' mathematics service programme for Physics students at the University of Leicester which has run since 1985. In addition it outlines a pilot project to use Problem-Based Learning (PBL) to address some of the issues raised by this programme. It concludes that whilst this limited experiment indicates that PBL does not help significantly in improving mathematical skills, the project has suggested some future developments.

Background

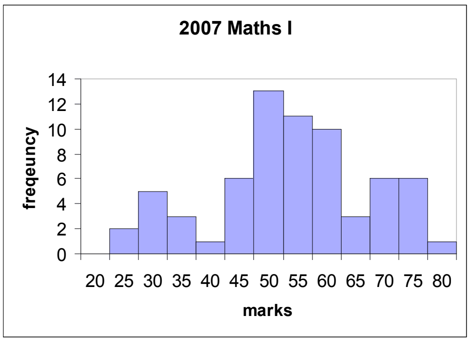
The Department of Physics at Leicester took over responsibility for the teaching of its 'service course' in mathematical techniques in 1984. One of the authors of this paper (DJR) led a teaching team of six academic staff from Mathematics and from Physics with backgrounds in mathematics with the ringing endorsement from colleagues that "*we couldn't make matters any worse*". The approach adopted several new features which will be discussed more fully below:

- No lectures: informal observations of student responses to questions during lectures led us to believe that the attention span of our typical undergraduate in a mathematics lecture was between five and ten minutes. Apart from its social aspect, the typical lecture was therefore a sparsely attended, error prone, dictation session. Rather than change the lecture, it was decided that the time of the teaching team would be better spent interacting with students in workshops and tutorials. More recently the 'no lectures' rule has been relaxed to include one lecture a week to introduce the material and provide help with reading the more difficult sections;
- A specially written text;
- Flexible pacing as a response to the dispersion of prior learning on entry.

Generative Mathematics

The standard format for the presentation of mathematics is theorem, proof, example, exercise. The example is usually a particular application of the general result stated in the theorem and then demonstrated in the proof, and the exercise is designed to allow the students to practice applying the theorem for themselves. Unfortunately the proof very often fails to illuminate why the theorem is really true: each step is seen to follow the previous step without providing any broader sense of where it is going. In any event, students do not learn the proofs but attempt to memorise the results in case they come up in the examination.

The sequence theorem-proof-example is not how mathematical results are typically generated (Burn, 2002): a general result emerges from a number of specific examples. Moreover, well-chosen examples often illustrate why the result is true. Thus, for the



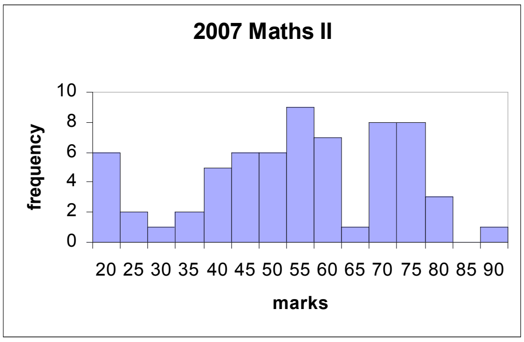


Table 1. Marks distribution on the two main techniques examination papers for the 2007 cohort showing the division into three groups. The majority of the failing students pass the re-sit examination.

purpose of a course in mathematical techniques for Physics, we can start with an example and follow this with an exercise. A well-chosen exercise will not be solvable by 'plug and chug' from the example, but will require an insight into how the example works. In some cases we might want to add the theorem as a reasonable generalisation; indeed in many cases the proof might be a generalisation of an example.

The Text

Since the text is not a '"self-study"' book it does not need to examine every potential confusion or every possible variation on a theme or go into a lot of background. The text covers all of the standard mathematics for Physics in 15 brief chapters each of approximately 15 pages. This provides a manageable quantity of reading and initiates the process of 'chunking' of mathematical knowledge.

Observations in tutorials have shown that many students enter university not knowing how to read mathematics. The text adopts a two-column format in which the formal mathematics appears in the right hand column and the thought processes behind the mathematics appear alongside in the left hand column.

Flexible Pacing

It is our belief that streaming students on the basis of their prior learning has a negative effect on motivation. Rather, each topic can be studied in either one or two weeks allowing both a difference in contact time and a quantifiable progression rate through the programme. The gaps created by progressing more rapidly are filled by higher-level work; by taking this more advanced core material early students create space for additional options and hence the opportunity to obtain a better class of degree.

Outcomes

Students attend one workshop and one tutorial per week and must submit for each a piece of work to be marked by the tutor as well as a multiple-choice paper to be marked by computer. In addition there are two end of term 'open book' test papers and ten hours of examinations. This level of assessment means that students must attempt all parts of the course. In addition it means that risk of failure is highly visible.

Interestingly, as illustrated in Table 1, the overall marks are tri-modal: one group of students is not significantly stretched by this material; a second group fail multiple modules; and a third group lies in between. Of the 1200 or so students who have been through the course, only 3 have ultimately not progressed because of a failure in the mathematics component alone.

Evaluation

Focus groups and observation of students have been used to obtain feedback on the course. The main issues that have emerged from the point of view of this paper are firstly that the programme is somewhat boring and secondly that many students still have only a limited ability applying mathematics in novel contexts in later work.

Problem-Based Learning

A major component of the Physics programme is taught through Problem-Based Learning (PBL) (Raine & Symons, 2005). In addition the Interdisciplinary Science programme is taught entirely by PBL with the exception of the skills component (which includes IT and mathematics). PBL is intended both to improve motivation by arousing student interest and to embed knowledge more securely by adopting a research approach. The question therefore arises as to whether PBL can be used in the context of service mathematics (Raine & Symons, 2006). To investigate this a PBL version of the first year mathematics service course for Year 1 Interdisciplinary Science students was prepared, hoping to address the following research questions:

- Is low performance in Mathematics amongst entrants to science degrees influenced by a negative attitude towards the subject?
- Can we change attitudes towards mathematics through PBL?
- Does an improved attitude towards mathematics coincide with an improvement in performance?

The number of students on the Interdisciplinary Science programme has been small (entries of 6, 12, 4, and 16 over the four years to date). It is unfortunate that the year in which the PBL programme was introduced coincided with the smallest entry of just 4 students. Nevertheless, the four students spanned a range of prior learning and attitudes and the research techniques used appear to have provided some useful results.

Pilot Evaluation Strategy

The pilot evaluation strategy had four components. First, to establish a baseline of mathematics knowledge, the students took a timed unseen 'test' prior to any teaching. Second, to establish a baseline for attitudes towards mathematics, students were interviewed as a group and their responses to a set of questions recorded. Finally, at the end of the year students were given a post-test with questions covering the same material as the pretest and, additionally, changes in attitudes were investigated through a second group interview.

Materials for PBL

Two types of material were developed as part of the pilot project: PBL questions and online videos. The PBL questions were sets of problems that formed the basis of weekly class meetings lasting 1 to 1.5 hours. The facilitator guided students through the knowledge they would need to tackle the problems and answered questions on this material. Standard textbooks were used and students were expected to complete the problems outside of the class.

Additionally, a set of short videos covering individual topics was produced: since each video addressed a single issue they were each no more than 5 minutes in length. The videos were made in a tutorial setting with the tutor interacting with a pair of students. This was intended to ensure that the viewer felt part of the group and was not being spoken at by a 'talking head'. It also enabled natural pauses during which the viewer could think alongside the video tutees. To allow single 'takes' we used a two camera set-up even though this added to the editing overheads. In addition we used an interactive whiteboard to record the mathematical writing directly and clearly; this also required editing. Our philosophy was to encourage students to view mathematics (at this level) as an encoding of what they already know. Hence, the commentary is correspondingly informal and more appropriate to a 'live' video presentation than a text.

The videos were placed on the University Virtual Learning Environment (VLE); unfortunately it was not possible to monitor their use since the statistics of site visits from the VLE are misleading in that they overestimate the number of actual viewings of the material. The videos are publicly available on the πCETL web site.

Pilot Evaluation

The points to emerge are as follows (Barker, 2008):

- There was some increase in positive attitudes toward mathematics amongst all four students who also expressed a greater confidence in tackling problems;
- There was some improvement in mathematics performance by the weaker of the students (+34% overall but the increase from 29% to 39% in average student marks is disappointing);
- There was a general dislike of the PBL approach to provide supporting skills. Students all felt that their main modules involved a constant diet of PBL; they wanted the mathematics classes to help them directly to tackle the problems they already had, not to add more problems;
- The video support materials were found to be useful.

The small improvements in attitude and ability are more likely therefore to have resulted from the attention they received as a small group than from the PBL approach.

Course Development

While the specific questions asked by the Project have received somewhat negative answers, the results of the Project have been greatly beneficial in several ways. Firstly, the materials from the Project will be embedded in the course: the videos are independent of the PBL approach and will be used to support both Physics and Interdisciplinary Science;

the PBL problems will be adapted as exercises to reinforce learning, especially for the stronger students. Secondly, the mathematics support course for Interdisciplinary Science has been redesigned in a novel way. A number of exercises on a given topic are set at the start of each week. Students who obtain full marks on the exercises are excused from mathematics classes. Other students attend an initial class where the material is explained. They then submit their attempts at the problems. There is then a second class where they are given feedback on their attempts and further assistance. The submission process and written feedback continues (in theory) until students can demonstrate competence (arbitrarily chosen as greater than 80%). This is reflected in the marking scheme which is 0 for each weekly unit until competence is achieved. This approach will be formally evaluated at the end of the session but attendance and submission rates as well as anecdotal evidence suggest that it is working very well.

Our conclusion for the mathematical techniques course for Physics students is that we should eschew any wholesale redesign along PBL lines, but that we should endeavour to link future mathematics teaching to existing PBL components and evaluate the results.

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Developing Mathematics Support for the Specialist Mathematician at Year 2 and Beyond

M. J. Grove, A. C. Croft & D. L. Bright

Abstract

In the recent past, measures have been put in place nationally to ensure that all students embarking upon undergraduate programmes with a strong mathematical content have access to resources that will ease their transition into Higher Education. However, evidence recently published refers to some problems emerging in later years, particularly Year 2 of single honours Mathematics programmes, with disillusionment amongst parts of the cohort and high drop-out rates, at least within some institutions. This ought to concern the mathematics community because, whereas the more widely reported 'mathematics problem' was largely concerned with a lack of fluency in basic mathematical skills amongst non-specialist 'users' of mathematics (e.g. engineers), the groups under consideration here self-select to study Mathematics at university. Furthermore, some of those who do succeed in Higher Education are not well-prepared for postgraduate study and concerns have been raised at the highest levels about the number and quality of 'home-grown' entrants to Mathematics PhD programmes and the long-term effects this may have upon the UK science base.

This paper will pose questions about the ways in which support might be developed so that undergraduate mathematicians in their second and third years might be better supported and encouraged to become even more confident, competent and independent learners. In doing so it is hoped to redefine the meaning of mathematics support and move it from being considered solely as a remedial model to one of enhancement.

The Challenge at the Transition

The Higher Education mathematical sciences community is well aware of the challenges facing those who teach mathematics to both specialist Mathematics students (those who come to university to study single and joint honours Mathematics programmes) and non-specialist 'users', such as engineers and physical scientists (Sutherland & Pozzi, 1995; London Mathematical Society, 1995; Hawkes & Savage, 2000; Institute of Physics, 2001). Increasingly however, other groups (for example those within the health and biological sciences, see Sabin, 2002 and Tariq, 2002) are also finding that their students neither possess the requisite mathematical skills nor are keen to acquire them.

Universities are adopting a number of approaches to tackling transitional problems, for example by the provision of summer schools, bridging mathematics courses (a detailed overview of such measures has been published, see LSTN MathsTEAM, 2003) and through mathematics support centres which many universities have now established (see Perkins & Croft, 2004). Universities now also have access to a range of quality resources that have been produced directly to support students: the FDTL4 project *Mathematics Support at the Transition to University* has developed **math**tutor, the FDTL4 project *Helping Engineers*

Learn Mathematics (HELM) produced workbooks, and the **math**centre project has produced numerous resources as well as an online resource bank.

Emerging Issues

While it would be untrue to say that the problem at the transition has been solved, it is the case that:

- An ample supply of free, good quality resources are available to help any students serious about remedying their shortcomings, and to help academic and support staff who aspire to assist students who struggle at the school/university interface;
- A significant proportion of universities have invested substantially to put palliative mechanisms in place (e.g. support centres); and
- There are several high profile, well-resourced national projects designed to increase the supply of mathematically qualified school leavers, and to improve teaching quality and continuing professional development of mathematics teachers.

However the 'mathematics problem' has several other dimensions. One is the 'mechanics problem' (see Robinson, 2005). There are others, and these impact upon the specialist mathematics community rather than non-specialist users of mathematics.

In 2003 Wiliam (in William, 2003) published work in respect of *Students' Experiences of Undergraduate Mathematics* arising from a three-year ESRC funded project that examined progress and attitudes of single honours Mathematics undergraduates in two research-led universities. Their report notes

> "*for many of those staying* [on the course] *attainment was average and below, the problems of coping with the work were accompanied by growing disillusionment with mathematics; generally, although with some exceptions, students enjoyment of the subject declined over time".*

Many did not adapt well to develop new styles of working in order to cope at university.

> "*Such students became mildly depressed in the second year and seemed to lack immediate sources of support and the motivation to seek these out".*

The research investigated failing second year students. From the same study, Macrae et al. write*:*

> *"it is difficult to know what more the university could do to support these struggling students especially as they tend to withdraw when faced with lack of success and many find it difficult to talk openly and honestly about their situation. However, faced with widening participation, universities need to put in place increased support structures to encourage struggling* [second year] *students to seek help before it is too late".*

However, it should be noted that these findings are not ubiquitous. For example, Povey & Angier, 2004, cite very different experiences of students in their own institution. Their context, though, was different in that the students they researched were all on Mathematics Education courses and training to become secondary school mathematics teachers. Their students' interaction with undergraduate mathematics was designed to be much more exploratory, negotiable, personal, social, supported and collaborative, and as they note, in clear contrast to the mathematics delivered rather more traditionally. The students they describe, whilst starting from a relatively weak background, went on to succeed. This is an important point, given the dire shortage of mathematics teachers in schools. It would be tragic if many of those students on single honours Mathematics courses who might make good teachers are turned off the subject because of the way it is delivered within Higher Education.

Secondly, concerns have been expressed about the quality and numbers of UK PhD entrants in the mathematical sciences and cognate disciplines. The Roberts Report – *SET for Success* – draws attention to the quality of PhD entrants to Science, Engineering and Technology departments:

> "*A particular concern of many respondents to the Review was the quality of PhD students, both at the commencement of their study and on completion of it."*

It noted also that there had been a slight decline, from 1996-1999, in the proportion of PhD entrants in Mathematics with a First or 2:1 degree despite the fact that, over the same period, there has been a slight increase in the proportion of such degrees awarded. However, the Mathematical Sciences continue to attract the highest proportion, over 95%, of such students across the SET disciplines which is quite different from the much lower proportions seen, for example, in Chemistry and Engineering. The Review did note that no firm conclusion should be drawn from their data in respect of mathematics.

The report *Where will the next generation of UK mathematicians come from?*, published by the Manchester Institute for Mathematical Sciences in 2005, notes:

> *"the domestic supply of mathematically competent manpower is in such decline that in many areas (including... post-doctoral fellows and appointments to academic positions) we are now dependent on trawling recruits from other countries"*

and

> *"In order to maintain the quality of postgraduate recruitment, public funds are increasingly being used to support students from other – mostly EU – countries."*

> *"It becomes essential to ensure that our national curriculum and incentive structure allows our schools and universities to produce home-grown research mathematicians of sufficient calibre to compete with those from other countries."*

An international review of UK Research in Mathematics was undertaken in 2004 on behalf of the EPSRC and the Council for the Mathematical Sciences (CMS). It was comprised of 13 world-leading mathematicians and statisticians all based outside the UK. Amongst other issues, they were asked to comment upon the adequacy of the current three-year PhD model prevalent in the UK.

"The system of three-year PhDs can only work if there is excellent A-Level education at the school level. Our perception is that A-Levels are weaker than they used to be. The result then is that this produces many students who cannot compete with graduates from abroad."

A recent report in the *Times Higher Education Supplement* (Tysome, 2007) notes that in the mathematical sciences approximately 30 percent of staff are from overseas; similarly, in Electrical, Electronic and Computer Engineering and in Physics, 34 per cent and 31 percent respectively of staff are from overseas. This compares with the 20 per cent figure across higher education as a whole. Whilst maintaining a good international mix of staff has many advantages, it is apparent that UK postgraduates will need to be ever better-prepared if they are to compete with well-qualified candidates from overseas. Furthermore, when a significant proportion of staff are recruited from overseas, there are challenges for the professional development of these staff to ensure that they are fully aware of the prior mathematical backgrounds and experiences of UK undergraduates, and that they modify their expectations and teaching styles accordingly.

In 2005 HEFCE designated Mathematics a *strategic and vulnerable subject* (HEFCE, 2005) and has since provided substantial funding to a major community-wide initiative to increase and widen participation within the mathematical sciences at university level (see Grove & Lawson, 2004). If the *more maths grads* Project is to be a success, then it is essential that the additional students recruited are not only retained throughout the entire duration of their programmes of study, but that they are also motivated and inspired to share their passion for mathematics with future generations. The Project therefore has a theme of activity looking at aspects of the Higher Education mathematical sciences curriculum.

Perhaps the most telling evidence of a problem comes from comments made by students themselves. The following two quotes are taken from two complaint letters written by final year undergraduate Mathematics students:

"I am now going into my final year when the workload is at its highest but I am not offered the same kind of support [as the first year students]...."

"Being a finalist this year is most important…It is hard to arrange appointments with our lecturers and you can't ask to sit in their office… and ask them for help when you get stuck…"

Supporting the Specialist and More Able Student

Given the evidence presented within the previous section a number of potential areas where support for the specialist and more-able student may be targeted can be identified:

- Improved pedagogies informed by existing research;
- Extension of the role of existing support mechanisms;
- Development of resources;
- Professional development of academic staff;
- New research, including into ways of developing independent learners;
- Support of new Mathematics postgraduates (not with teaching but with focussed research and study skills).

These areas give rise to many questions: How can existing pedagogic research be used to improve practice? Is it possible to understand better the identities of students who choose to learn Mathematics? In what ways are they, and their learning styles, different from their predecessors and can we adapt our methods of teaching and their methods of learning in order to better achieve our objectives?

Much effort has been expended in developing mathematics support centres and other mechanisms at the transition. Can and should these be extended to offer support to students in later years? Is it sufficient to say that if these students cannot cope in Year 2 then the problem is theirs not ours? What does this say about the current design of our programmes and our university admissions procedures?

Are there any resources that could be developed and made available nationally in order to help at least some of these students? Whilst it is obvious that specialisms increasingly emerge as students progress through the Higher Education system, there may be a core of material which most students should be required to understand. Is there such a core and can resources be developed to support it?

There is undoubtedly a role for the professional development of academic staff. The gap between student performance and staff expectations continues to widen. The myriad of changes in schools and the increasing recruitment of staff from overseas means that many are unfamiliar with the UK education system and what it is delivering. How this professional development can be incorporated when staff have substantial, and very different, demands placed upon them will surely continue to be a source of tension.

There is a need for more pedagogic research intended to bring about positive change in the lecture theatre and the classroom. Too many students are disengaged from what is on offer now, but the community does not understand why, nor what can be done about it. Practice which is working well needs to be better disseminated and taken-up elsewhere.

Moving Towards Programmes of Support for the Specialist and More Able Student

Since 2006, the Maths, Stats & OR Network and **sigma** (the Centre for Excellence in Mathematics and Statistics Support) has delivered a programme of activity to support specialist Mathematics students during the later years of their undergraduate courses. Two mini-projects have currently been funded: one will create a professional development DVD on the teaching of proof to undergraduate students, and the other will develop and trial an independent study module. These are complemented by several other ongoing Network mini-projects. The Network has also initiated a programme of resource development to align with this theme, and a Statistics Facts, Formulae and Information Leaflet, which is targeted beyond the first year, is now available.

sigma is currently undertaking an action research project that will explore, implement and evaluate supporting mechanisms at Year 2 and beyond, particularly for the more able student. A component of this activity has involved exploring the prior mathematical experiences of postgraduate students so as to better understand progression patterns and motivating factors for continued study within the mathematical sciences. This work is still at an early stage, but some interesting findings have begun to emerge. The students themselves comment that:

- Further mathematics support for Mathematics undergraduates is needed at the transition into Year 2, as new and more abstract topics are introduced;
- Informal peer support is the first choice of mathematics support for many;
- Many students welcome the opportunity to both give and receive formal peer support;
- Postgraduate communities of practice within the department are important in order to encourage a sense of belonging.

This work has indicated that many, though not all, students value opportunities to interact with each other on learning activities as much as they value direct one-on-one support from an academic member of staff. There is a greater emphasis on the development of student learning communities throughout undergraduate programmes than may have first been realised. This is clearly an area worthy of further investigation.

In October 2007, **sigma** opened a resource and activity centre for students in Year 2 and beyond. This is not be staffed in the same way that the Mathematics Support Centre at Loughborough is, but provides a social learning space for these students. A programme of research is being undertaken to investigate how students use this resource and any effect it has upon their learning experience in mathematics.

Conclusions

Traditionally, mathematics support has focussed upon those students with mathematical deficiencies, but there is a growing collection of evidence that calls for support for the specialist and more-able student. To address the needs of such students, mathematics support needs to move away from being considered a remedial model to one of enhancement where the focus is upon improving grades, and the deeper understanding of mathematical concepts and ideas. Further investigation across a variety of themes is required, but a programme of activity is underway that is beginning to yield interesting results. The authors warmly welcome further support, advice and guidance from those within the mathematical sciences community.

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Mathematics Support – Real, Virtual and Mobile

A. C. Croft

Abstract

The majority of UK universities now offer 'real' mathematics support provision through, for example, support centres. The initiatives '**math**centre' and '**math**tutor' have striven to provide enhancements to this real provision which are accessible to all: on-line and on-disc for whenever students want to access it. Recent technological developments with handheld devices, notably the Apple video iPod, PDAs, 3G mobile telephones, the PlayStation Portable and other game stations, are presenting new opportunities to allow mathematics support to become mobile. This paper outlines the evolution from real to first virtual and now mobile support provided through the initiatives **math**centre and **math**tutor. Examples of what is currently possible are described, and indications for future work are outlined.

Introduction

In the face of a well-documented decline in the level of mathematical skills displayed by students on entry to university (see references below) most HEIs have made efforts to offer various forms of additional provision. In addition there have been numerous national projects which aim to provide resources to assist lecturers who are trying to find ways of better supporting struggling students. In 2001 an extensive review of the range of support available was conducted by the then LTSN (Learning & Teaching Support Network, now the Higher Education Academy) through the MathsTEAM project. Details can be found via http://ltsn.mathstore.ac.uk/mathsteam/. This paper outlines how one particular type of additional provision, namely the Mathematics Support Centre, has evolved from one which relied upon a fixed physical location, through the provision of e-support using DVD and internet technologies, to its latest manifestation m-learning (or mobile-learning) resources available on mobile devices such as telephones.

Physical Support Centres

Since the 1990s many universities have developed 'real' mathematics support centres. These are dedicated facilities located within universities within which students can work, access learning resources, and seek one-to-one help with teaching staff. Two early and successful centres were those at Coventry University, developed by Professor Duncan Lawson, and at Loughborough University by Professor Tony Croft. In 2001 Lawson and Croft undertook a study on behalf of the LTSN to investigate how widespread this kind of learning support provision was, to identify elements of good practice, and to disseminate findings throughout the Higher Education community. Details of this study can be found in (Lawson, Halpin and Croft, 2001a; Lawson, Halpin and Croft, 2001b) and the resulting Good Practice Guide (Lawson, Halpin and Croft, 2001c). In the 2001 study a total of 95 UK HEIs replied to the basic question of whether they had some kind of mathematics support centre; this being regarded as an umbrella term encompassing a wide range of provision. Out of the 95 replies, 46 indicated that they offered mathematics support provision whilst 49 said they did not. The key element of this provision, which was identified most often by respondents, was the availability of one-to-one support. From the study it was possible to distil elements of good practice, and report upon those facilities and resources most favoured and most used by students. In the main, students visited support centres to seek one-to-one help and to access short, accessible, paper-based help leaflets. This finding was important in informing the subsequent e-support developments **math**tutor and **math**centre. In 2004, Perkin and Croft (Perkin and Croft, 2004) carried out a follow-up survey because it was apparent that many more institutions were, by then, developing provision. 106 universities were identified across the UK and surveyed. Only 5 did not respond. 66 out of the 106 said that they offered mathematics support over and above what would traditionally have been provided. An interesting finding was that 11 out of 19 Russell Group institutions were now offering mathematics support. Indeed, by 2004 support centres could be found across the full range of HEIs. The MSOR Network, in conjunction with the Mathematics Learning Support Centre at Loughborough University, made many paper-based resources available to the Higher Education community, either free of charge or at cost. Two in particular which have proved to be particularly popular and useful have been *An Algebra Refresher*, which is a workbook containing hundreds of exercises aimed at better preparing students for university level work, and a *Facts and Formulae* leaflet of which over 100,000 copies have now been requested by and distributed to university departments. Copies, for those working within UK HEIs, can be requested by emailing info@mathstore.ac.uk.

DVD and On-Line Support

As technology advanced and universities moved more into e-learning it was not surprising that mathematics support should also be provided on-line. Some groups of students such as part-timers and mature students with family responsibilities can find it difficult to access the physical support centre because their time on campus is limited. The provision of internet-based resources enables any students to access support at a time and place of their choosing. Many institutions developed their own on-line provision. However, it was realised that, just as had occurred with the development of paper-based resources in support centres, there was the likelihood of much duplication of effort if each university developed its own on-line mathematics support.

The LTSN therefore provided funding to develop a pilot virtual support centre now known as **math**centre (http://www.mathcentre.ac.uk). This web-site provides a collection of resources including short leaflets, longer 'Teach Yourself' booklets and interactive exercises. The site is structured so that students can indicate their discipline and then be presented with resources that are appropriate. Alternatively students can simply use the site's search tool and enter the topic on which they wish to work and they will then be presented with a complete list of all the resources on this topic that are held in **math**centre's database. The site can be used by staff as well as students. Staff have two additional facilities: firstly, they can download handouts in bundles. So, for example, if someone wishes to establish a physical support centre at their own institution and requires handouts on a range of topics to be available in their centre, they can download a bundle of handouts in one go (whereas students have to download resources one at a time).

The second additional facility is a collection of teaching resources such as the MathsTEAM booklets. Although the site was available in September 2003, at this time it contained very few resources. During the academic year 2003/4 the volume of resources was increased significantly. In October 2004 there was a promotional campaign to inform students of the

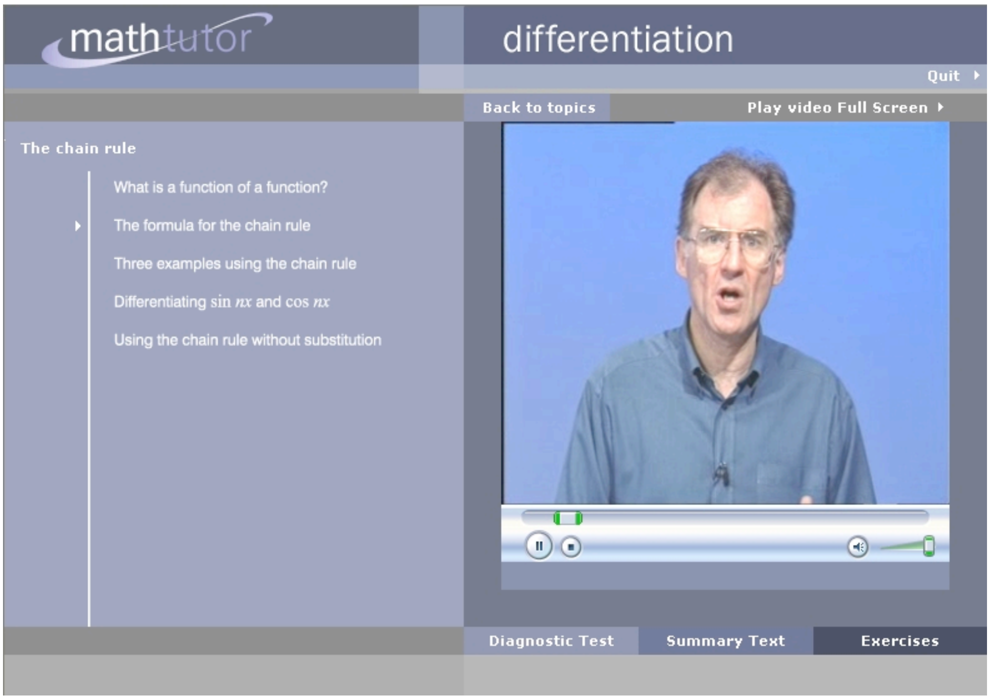

Figure 1. A screenshot of **math**tutor with a video tutorial on the Chain Rule playing.

existence of the site and in the early stages of their university careers many students did access the site (with a peak of over 300,000 hits in November 2004). However, this high level of usage was not sustained and the number of hits in Autumn 2007 is around 250,000 per month. The reduction, though, coincided with the launch of the sister site, **math**tutor (see below). Analysis of the resources being accessed show that by far the most popular resources are the quick reference, two sides of A4, help leaflets. In second place are the more substantial 'Teach Yourself' booklets, which are free-standing companions to the video resources which have more recently become available (see below). Whilst the usage statistics indicate that **math**centre is a very worthwhile resource, it was recognised that it did not provide the interaction with a tutor that students regard as the most popular resource in physical support centres. The Fund for the Development of Teaching and Learning (FDTL) project **math**tutor sought to address this deficiency. The resources of **math**tutor are based around a video tutorial in which a teacher introduces a mathematical topic, explains the underlying theory and carries out a number of worked examples. Linked to the video tutorial are a range of resources:

- Diagnostic exercises that allow students to self-assess their knowledge in the topic under consideration;
- Text resources that can be printed by the student and used as notes on the topic – the texts follow the video tutorial in terms of the order in which the material is presented and the worked examples provided;
- Interactive exercises that allow students to practise the skills and concepts that have been taught in the video tutorial;
- Extension materials which provide a context or application of some topics;
- Animations which graphically illustrate the material, for example, the proof of Pythagoras' Theorem and the addition of two sine waves.

Figure 2 (Left). iPod with animation of Pythagoras' Theorem.
Figure 3 (Right). Mobile phone with video tutorial on parametric differentiation.

These resources were initially provided on seven DVD-ROMs. However, advances in technology have enabled integrated, easily navigable resources to be provided over the internet as well (http://www.mathtutor.ac.uk). Figure 1 shows a screen shot of **math**tutor with a video playing. The **math**tutor video tutorials are now also available on the **math**centre site.

m-learning

From the middle of the current decade mobile technologies became ubiquitous, with the majority of young people having ready access to mobile telephones, MP3/4 players and portable gaming devices. A natural development of the **math**centre/**math**tutor project has been to investigate the viability of converting existing resources so that they can run on these devices. Early indications are that it is possible to overcome technical limitations and display video and mathematically-based text materials. Over 80 hours of mathematics video material and animations from the **math**tutor project have been converted into a form suitable for playing on video iPods. Samples of these can be downloaded from the **math**centre website. Resources which can be played on mobile phones will be available shortly. Figures 2-4 show a variety of mobile devices for which mathematics support materials are available. Technical reports, funded by **sigma**, the CETL in Mathematics and Statsitics Support, which explain how these developments have been achieved are available by contacting **sigma** (www.sigma-cetl.ac.uk). However, important pedagogic issues remain to be addressed. We simply do not yet know whether significant numbers of students will be prepared to access learning resources in this way, whether they will want to, and how successful such means of delivery will be. These are issues being addressed by staff working for **sigma**. Findings will be made available at future CETL-MSOR annual conferences.

Figure 4. Playstation Portable with interactive exercises on factorisation.

Conclusions

Mathematics support was originally founded on personal interaction with a tutor. This is a costly method of support which, moreover, cannot possibly be accessible at all times for all students. It is therefore helpful to supplement this mode with other resources. Internet-based resources do not have the restrictions of time and place that a physical support centre has, and through free access, allow support to be provided to many more students. However, these resources do still require a PC and, notwithstanding the growth in laptop ownership and wireless provision, this still represents a limitation. New technology such as the video iPod enables mathematics support to be available in a much more mobile way. Resource development for mobile mathematics support is still in its infancy but the potential is undeniable.

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EPILOGUE

Affordability, Adaptability, Approachability, and Sustainability

J. Kyle

Looking back, this St Andrews meeting was, to my mind, a watershed of sorts. Although I might not have put it in these terms at the time, I probably regarded mathematics support as a form of cottage industry practised by a few well meaning, possibly eccentric, individuals, who may themselves have been hard pushed to offer a credible rationale for this work. I have a vivid memory of listening to Tony Croft, whom I regard as one of the founding forefathers of mathematics support in the UK, reflecting quite eloquently and with real concern, whether in some structural senses support centres might possibly do more harm than good in the long run. It was the work of this timely meeting, co-ordinated by the indefatigable Christie Marr, which allowed us to begin to marshal the arguments to convince possible sceptics that mathematics support could and should fit seamlessly into a larger geography of teaching and learning.

The earlier chapters of these Proceedings record the main business of the meeting of addressing the quantitative skills gap and sustaining Mathematical Support in Higher Education. But for me, the indications of greater possibilities in the future emerged during the closing debate on *Affordability, Adaptability, Approachability, and Sustainability*. Among the chief fears a chair faces is facilitating a discussion on affordability. The great and sterile danger is that the discussion degenerates into a list of financial complaints culminating in a resounding 'No'. It was therefore a pleasant and uplifting experience to find that, despite some realistic concerns over funding, the debate reached, overwhelmingly, the conclusion that we cannot afford not to act.

The debates surrounding adaptability and approachability, while less dominated by concerns over resources, were less certain in tone. My notes from the day indicate that a short but perceptive intervention from Celia Hoyles distilled the debate and essentially exhorted all to have the courage to make the important transition from practitioners of mathematics support to advocates of mathematics support, possibly after gathering more data. When the discussion moved on to sustainability, two distinct and opposing thoughts emerged. Some colleagues regarded mathematics support as an intrinsically temporary device introduced to deal with structural curricular defects: remove the defects and mathematics support should no longer be necessary. Others talked in terms of mathematics support becoming a permanent feature in the teaching and learning landscape: an additional but quite distinct means to enhance provision for learners, however well designed the curriculum may be.

We concluded our meeting in optimism, perhaps tinged with apprehension, and a determination to tackle the remaining challenges. Was our optimism justified? I offer just two subsequent quotations.

> "[Universities should] *provide additional academic support for students, for example those struggling with mathematical elements of their course."*
> Staying the course: a review of student retention by the House of Commons Committee of Public Accounts (2008).

"*The provision for some sort of 'drop-in' mathematics support facility is a strong recommendation.*"
Advisory Committee on Mathematics Education Annual Conference (2008).

Other evidence for the sustainability and transferability of the underlying concept has emerged from similar recent developments within the Higher Education sector in the Republic of Ireland.

Now only a few years on, we see that the concept of mathematics support has not only become firmly embedded in UK Higher Education, but colleagues have moved on to gather data on the way students use such resources and look for optimal strategies for the delivery of this support, and this is perhaps the most convincing evidence of acceptance. Mathematics support came of age in the first decade of the 21st century. What might once have been described as a cottage industry now plays a respected and widely adopted role in Higher Education and a major catalyst for the transformation was this conference at St. Andrews in June 2007.