Maths at University

Reflections on experience, practice and provision

Mike Robinson, Neil Challis and
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more maths grads
multiplying opportunities

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Editors: Mike Robinson, Neil Challis and Mike Thomlinson

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1.1 Introduction:

the More Maths Grads Higher Education Curriculum Theme

Introduction: the More Maths Grads Higher Education Curriculum Theme

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One of the quieter aspects of the More Maths Grads (MMG) project [1], although there have been several talks, presentations, conference sessions and workshops, seminars and publications, has been the so-called HE Curriculum theme. Actually this may be a slight misnomer. The theme is only partly concerned with curriculum content per se, although some issues have arisen in that respect. It is as much about understanding and improving the kind of experience we provide for our students of mathematics, how we teach them, engage them and support them and recognise their aspirations, how they feel about that experience, and what the implications are of all that.

The rationale is this: the MMG project workers have been working hard, both with potential students and with employers, to explore the best ways to generate more interest in and enthusiasm for mathematics, and therefore more applicants perhaps from a wider base, and thus more graduates. It therefore behoves us to understand and share what is good about the courses into which the beneficiaries of this push for more maths grads are walking.

So one of our major activities over the period of the project has been to explore and review the way mathematics courses are working in the four institutions directly involved in the project (Coventry University, University of Leeds, Queen Mary, University of London and our own Sheffield Hallam University). We have administered questionnaires, with new first year students in induction week and subsequently with students across all years of their courses, and we have held group and individual semi-structured interviews, with first year students, with postgraduate tutors, and with lecturers.

We have been fascinated at some of what has emerged from all this exploration, and we hope readers of our writings here and elsewhere will share that fascination. We might say:

> *"...the end of all our exploring will be to arrive where we started and know the place for the first time." (T.S. Eliot, Little Gidding)*

Of course, "for the first time" is an exaggeration: some but not all of what we say is original, but it is based upon what we have found. We have held up a mirror to parts of our community of university mathematicians who run undergraduate mathematics courses, and we are part of that community. One aim in publishing these articles is to create conversations, to stimulate debate, and perhaps then to encourage experimentation and change. We hope to engender reflection, to increase our understanding of how our community works, how it is seen by students and how it is seen by staff. In places we might hope people will think about how something that seems to work well in one context may help to inform improvements in another.

One of our project targets has been to produce this current publication. Its working title prior to birth was the *Good Practice Guide,* but we were wary of the claims implicit in that title. We are aware that what works in one place and time may not be transferable unmodified, and those who are local know best what will work. We then thought we might prefer to call it *A collection of good wheezes for which there is some evidence that they have worked well in one place at one time, when operated by a particular person, and which the reader might like to reflect upon to see if the idea would help them to improve what they offer.* We commented at the time that this was a little less catchy. As things have turned out, and as the reader will see in what follows, this rather clumsier version still does not quite capture it.

In the end we have settled for *Maths at University: reflections on experience, practice and provision*. The reader will judge if that is the right title, and we can start that process by briefly describing what is to be found hereafter. This book is a series of stand-alone articles. Some of these have appeared elsewhere before, one in Mathematics Today and several in MSOR Connections, although much of what is here is appearing in print for the first time. This explains some degree of repetition and the lack of a single narrative through the book.

In Chapter 2 we look at some aspects of how our students end up as our students: what do they say when we ask them why they are studying maths, and what effect does geographical location have on available choices? We have had a particular brief to look at the experiences of and issues facing mature students and adults returning to study – an under-represented bunch in mathematics. Finally in this section, we respond to the fact that we in universities know that mathematics degrees are diverse in nature, from highly theoretical to highly practical passing through all points in between, but it turns out that many other people do not. This has led us to design the booklet *Maths at University: start to finish – your guide to maths at university*, to be widely distributed in the hope that we can help students to choose the best maths degree for them; we shamelessly give this a plug here.

Chapter 3 gives the students a serious chance to tell us how they feel. What do they say about how their confidence in and enjoyment of mathematics is affected by their university experience? What do they say are the best and worst things about their courses and experiences, and what would they do to improve things? How do they deal with the transitions involved in going to and passing through university? To enliven the mix, and we do believe it does that, we bring in what the staff say about their students. There is much enjoyment and food for thought here, and as such these papers could serve as an introduction to the material covered in later chapters.

In Chapter 4 we investigate where our students say they get their support from, and meet again the powerful notion of a mathematical community which emerged in Chapter 3. This is the first place where we meet case studies contributed by other authors, which we hope will enrich this publication. These were invited or commissioned by ourselves with the help of Michael Grove, and in this section contributions from Tony Croft, John Goodband, Peter Samuels, Jeff Waldock and Louise Walker cover peer-assisted learning, progress files, maths support centres, and making something positive of Facebook!

In Chapter 5 we report on student and staff views of teaching, both in lectures and smaller groups, and how we may engage students actively; case studies presented by Joel Feinstein and Thomas Prellberg add something extra.

Chapter 6 addresses assessment, its centrality, its nature and balance and how it interacts with retention of students. Chris Sangwin contributes some of his wide experience with automated marking.

In Chapter 7, we finally meet the word curriculum, addressing content and course design. We present some radical and deliberately provocative thoughts on curriculum content and our shared notion of what constitutes a maths graduate. Case studies to embellish this come from Bill Cox, Kevin Houston and Franco Vivaldi.

We also address the employer engagement angle, considering the place of employability skills and careers awareness in the curriculum, and finally discussing what the mathematics community may have to contribute to the foundation degree and workforce upskilling agenda. Case studies come from Neil Challis and Stephen Hibberd, both discussing group projects.

We finish in Section 8 by doing two things. We summarise what we perceive as having emerged from our data gathering and musings, and we talk about our reflections in two senses, both in terms of what we see in the mirror we have held up to ourselves, and in terms of what we think about that. In particular we look for common themes and issues which have emerged, although we will not steal thunder from our conclusions by saying more here.

Our collection of interesting stories and “good wheezes” arising from our researches is of course not comprehensive. In some cases we report what the Times has been pleased to call the bleeding obvious, but sometimes a reminder about the obvious is useful. In other cases there are some interesting and unusual things which we hope will provoke, and provide food for thought and get the community talking.

[1] More Maths Grads (2010) last accessed on 06/01/10 at <www.moremathsgrads.org.uk>

This introduction contains smatterings of and paraphrases from an introductory article which appeared in MSOR Connections some time ago:

Challis N, Robinson M and Thomlinson M (2009) *The More Maths Grads project* MSOR Connections Volume 9(1), pp 34-35

2.0 Access to mathematics degrees

how and why do they get here?

2.1 *Why do students study maths?*

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1 Introduction

The More Maths Grads project has a central aim, encapsulated in its title, of increasing the number of students choosing to study maths at university. In effect, we hope that through a combination of outreach in schools, working with teachers and HE lecturers, improving careers advice and information about university, and other measures, we can persuade some students who would otherwise study a different subject, or not study at university at all, to apply for mathematics courses.

To that end, it is vital to consider the motivation that drives student decisions to apply to study maths. We surveyed 223 students on arrival at mathematics departments in a handful of diverse institutions, and later interviewed groups of students at the same institutions. In addition, we conducted a second survey of students across all years in the same institutions.

Because the first survey was conducted during induction sessions, the students were most likely the vast majority of the new entrants to the courses. The students who were interviewed were self-selecting and because of the time and commitment involved, it could be argued that these students are most likely to be unrepresentative to some degree. The second survey was open to all years, and took about 10 minutes, with prizes offered for completing the survey and the option to remain anonymous. In all 126 students took part; given the nature of the study we cannot guarantee that they are a representative sample. For more information about the second survey methodology, see [1].
In this paper we present the information they gave us about their decision to study mathematics at their particular university. We focus here on the 'standard entry' students, ie those who have come directly from school or sixth form college, or have taken a single 'gap year' before arriving at university. Mature students with a longer break between school and university are considered more fully elsewhere [2].

2 Experience of mathematics before university

We might expect that, given their choice of university subject, students on mathematics courses would rate maths as their favourite subject at GCSE and A level (or equivalent). Whilst the majority do indeed say this, a sizeable minority do not do so, particularly at GCSE. Table 1 shows the data.

	Favourite	**Not Favourite**
GCSE or equivalent	147 (67.1%)	72 (32.9%)
A level or equivalent	184 (83.3%)	37 (16.7%)

Table 1: Number of students (percentage of those who answered the question) who said Mathematics was their favourite subject.

3 Why do a degree at all?

We asked students firstly "What is the most important reason for your deciding to go to university?" Because of the open-ended nature of this question, their answers are hard to categorise precisely. Some, for example, said "to get a good job" without saying what, to them, would be important in a future career, whereas others were more specific about what aspects were of concern to them, citing for example pay, enjoyment, and ease of finding employment. In addition, some students dodged our request for the most important reason and gave more than one in the same answer.

With this caveat, nevertheless we have tried to categorise what students said, and the results are shown in Table 2. The first five categories (a "good" job, ease of finding employment, good pay, specific careers and job satisfaction) are all clearly career related, and in total around 56% give these as their main reason for going to university. The next two categories (to continue in education, and to gain a degree) could be seen as educational or career-related. Together they were cited by almost 20% of students. Thus, depending on how we view these latter two categories, somewhere between 56 and 76% of students cite career-related reasons for coming to university.

The next largest category was those students who wanted to experience university life. Their reasons included a desire for personal development, especially to become more independent ("a life experience to find who I am", "to learn how to look after myself"), and more immediate pleasures ("enjoying student life", "my sister went and she said it was great").

From the perspective of HE maths professionals, the disappointing news is that passion for the subject is rarely cited as the main reason for coming to university. About 1/8 of students said learning more maths or enjoying the subject was their main motivator for coming to university.

Future employment related reasons			**120**	**(56.3%)**
• 'Good' job	60	(28.2%)		
• Ease of employment	36	(16.9%)		
• Good pay	15	(7.0%)		
• Specific career	6	(2.8%)		
• Job satisfaction	3	(1.4%)		
Education and/or career related			**42**	**(19.7%)**
• Continue education	28	(13.1%)		
• To gain qualifications	14	(6.6%)		
Subject related			**27**	**(12.7%)**
• To learn more maths	17	(8.0%)		
• Enjoyment of maths	10	(4.7%)		
Other			**53**	**(24.9%)**
• The 'experience'	32	(15.0%)		
• Delaying tactic	6	(2.8%)		
• Miscellaneous	15	(7.0%)		

Table 2:
Most important reason for going to university. The table shows the number of times each category was cited and the proportion of students who cited this category as a percentage (1dp) of the total number of respondents (213). Because some students gave more than one reason, the percentages shown sum to more than 100.

Having asked students this open-ended question, we then gave them rather more prompting, listing a set of possible reasons for coming to university and asking them to rate each of these as 'very important', 'quite important', 'not very important' or 'not at all important'. Figure 1 shows the proportion of students who rated these statements in each category. The results reflect the open-ended question discussed above, in that needing a degree in order to get a good job is rated highest, but once students can give more than one reason, interest in the subject is, thankfully, a greater motivating factor than appeared above.

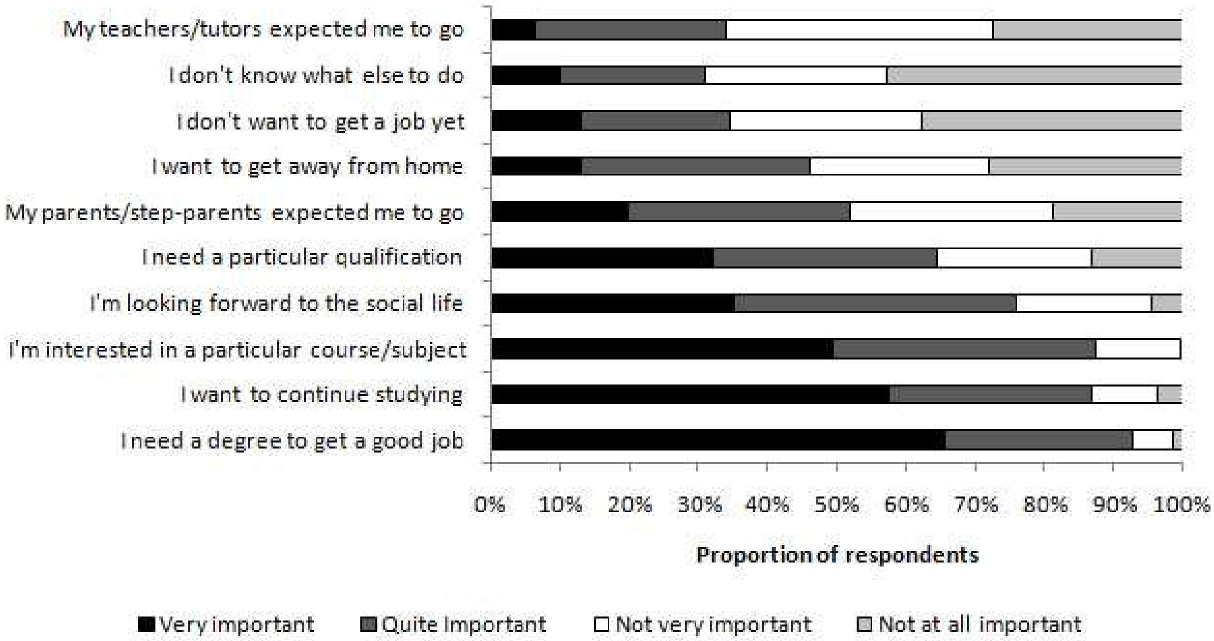

Figure 1:
Proportion of respondents who rated each statement as very, quite, not very or not at all important in their decision to go to university. Number of respondents 220-223, depending on the statement.

A similar broad spectrum of student aspirations about their time at university emerged when we asked them to rate the importance of various opportunities afforded them by university study. The results are shown in Figure 2. Although the opportunity rated 'very important' by the highest proportion of students was, again, 'increasing my employability', it is clear from these results that learning about the subject, enjoyment of university life, developing skills etc are all rated highly.

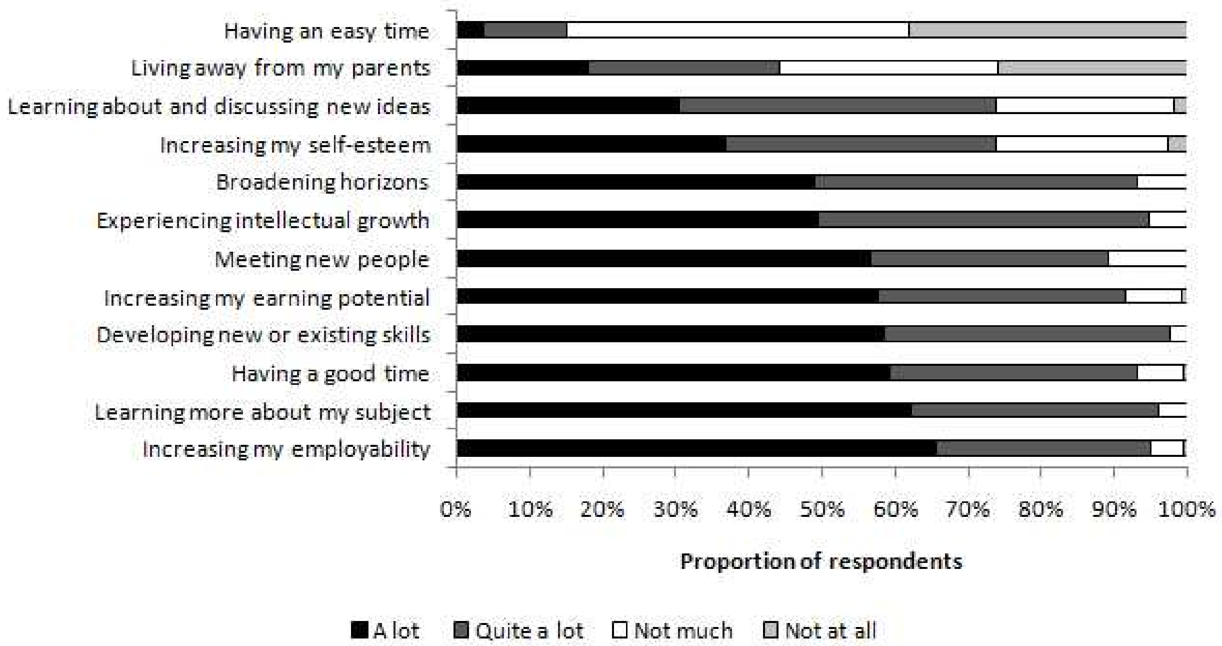

Figure 2:
Proportion of respondents who rated these opportunities afforded by HE study as very, quite, not very or not at all important to them. Number of respondents 218-223.

In summary, whilst, as we would expect, a range of factors are significant in a student's decision to come to university, the single biggest driver is that of the students' future employment. This no doubt supports Government efforts to make university courses more aligned to employment needs [3], whilst being perhaps at odds with more liberal ideals of the value of higher education and passion for our subject shared by these authors, and perhaps by many others in the profession. As two colleagues put it

> *"I mean, they're, why are they doing a degree? They're doing a degree to get a job and to earn a decent salary and hopefully buy a house and to be able to, you know, do all these things that people want to do. I mean, that's why they're going to university most of them. [...] You know, we get all wrapped up in the syllabus and maths, definitions and proofs but, but our typical student wants a good 2i and a good job."*

> *"Well the main thing is I think they're just trying to get the degree at the end of the day, to get the job or whatever. The motivation doesn't seem to be, for many of them, just a general interest in the subject."*

The latter quote suggests that 'many' students are not really interested in the subject. However, whilst we have seen career considerations are primary in coming to university in the first place, interest in the subject is also widely cited. At this point, let us turn to that specific question, crucial to our aim of increasing the number of mathematics graduates, and ask…

4 …Why maths?

As with the questions about reasons for choosing to do a degree, when we came to ask students about why they had chosen maths we first asked an open-ended question asking them "What was the most important reason for choosing to study mathematics?" The open-ended question, whilst interesting in that it didn't prompt the student at all, is again relatively hard to classify. Our attempt to do so is shown in Table 3.

Subject enjoyment			**135**	**(62.5%)**
• Enjoying maths	109	(50.5%)		
• Mathematics is favourite subject	16	(7.4%)		
• Wanting to learn more maths	12	(5.6%)		
• The challenge	9	(4.2%)		
Subject ability			**49**	**(22.7%)**
• Good at maths	37	(17.1%)		
• Best at maths compared with other subjects	13	(6.0%)		
Subject enjoyment/ability combined			**160**	**(74.1%)**
Career related			**70**	**(32.4%)**
• "Good job prospects"	37	(17.1%)		
• Prestigious/valued degree	16	(7.4%)		
• Specific career plans	9	(4.2%)		
• Wide range of jobs open to maths graduates	7	(3.2%)		
• Earning potential	4	(1.9%)		
Miscellaneous	15	(6.9%)		

Table 3:
Most important reason for choosing to study mathematics. The table shows the number of times each category was cited and the proportion of students who cited this category as a percentage (1dp) of the total number of respondents (216). Because some students gave more than one reason, the percentages shown sum to more than 100.

We would draw attention to two points of note from Table 3.

Firstly, encouragingly, three-quarters of the students cite their enjoyment and/or their ability at mathematics as the single biggest reason for studying it. However, these categories include a range from being the "only subject I was good at" through to a student talking about their "passion" for maths. For this reason in Table 3 we have separated out some of the range of statements students made to give a flavour of what they said.

Secondly, even in this question, career considerations are mentioned by a substantial minority of respondents. This is not generally about their having specific career plans (just 4% cite this, and as we shall see later in Section 5, relatively few students have definite plans at this stage) but rather about overall job prospects. As one student put it

> *"Good future job prospects, it teaches you good, core skills that will be very useful later on."*

Of course, few students have a single reason for choosing the subject. In our interviews with students, a broader picture of the factors emerges. Students talked together about enjoyment and ability in the subject, and some suggested a certain inevitability from a relatively early age. The following exchange was from a group of students at a university with a typical UCAS offer of straight As, and therefore these students would, presumably, have been qualified to study almost any subject related to their A levels:

> *Student 1: "It was really a simple choice for me, because maths is the only subject I'm good at. Everything else, you know, English… sciences I was all right at – physics, chemistry, biology but didn't want to go there. But mainly physics, chemistry, maths they were my strongest subjects. I was also a music scholar but music just wasn't for me. So it was either music or maths. And there was no choice, so it had to be maths."*
>
> *Interviewer: "Okay. What about you others? Cathy?"*
>
> *Cathy: "Yeah, pretty similar actually. I always have enjoyed maths ever since sort of early on in primary school even. I had a couple of choices to do with doing say maybe philosophy, but I just, it was always going to be maths for me, it, yeah, it is one of the few things I was good at."*
>
> *Interviewer: "Same with you, Elizabeth?"*
>
> *Elizabeth: "Pretty much the same you know, I've always been good at maths since primary school. So you know, whenever in secondary school we were made to choose GCSE add[itional] maths was an obvious choice. And when we were made to choose A Level, maths and further maths were obvious choices for me. So university there was no other option for me. I did consider maths and physics, but then I was like, no I don't really like the physics I'm doing so I'll just do the maths thing."*

[Student names changed]

These students sound as though they opted very positively for maths, but for others the decision, whilst still related to their ability and enjoyment of maths, sounds less positive and more related to what they felt able to do.

> *"Process of elimination. I was doing maths, physics, English language, media, further maths and general, you can't do general, media's useless, everyone does English, and I can't do physics, so I've taken maths."*

For other students however, the decision to take maths seems much weaker; indeed some did not choose it at first. Two originally had very different intentions.

> *Student 1: "Well I initially, I applied to do a law degree but then on the day of results I didn't meet my [offer] and when I was ringing around doing clearing [this university] offered me a place for maths. And maths was always something I'd enjoyed, but I just never thought I'd be good enough to do it degree level."*
>
> *Student 2: "Kind of the same for me, I applied to do law but I didn't get the three A's, I got two A's and a B so they offered me chemistry instead [here] but I didn't want to do chemistry. So I rung up and they said 'well you did better in maths than you did in chemistry'."*

These students were influenced as much by geography as by subject related issues.

> *Student 1: "I chose [here] because on the day of clearing I had a choice either to do law at Exeter or maths [here], and I'm from London and London's a big city, and the degree at Exeter was at Cornwall campus which is really quiet, so I thought I'd like [this city] more as a place,"*

whereas for another it was staying local to their home that mattered.

> *Student 2: "That's kind of similar 'cos I got offered law at Liverpool and maths with finance [here], but 'cos I already live [here] anyway even though I have already moved out but there's a lot of stuff that I wanted to continue doing like I go dancing and I watch [the local rugby team], I've got a season ticket, so obviously if I'd have gone to Liverpool I'd have had to stop a lot of stuff that I love, so I decided to come [here]."*

One of the messages from this might be that we, as staff teaching on maths courses, need to remember that some of our students are less than passionate about the subject, even in institutions which 'select' rather than 'recruit' students.

A number of students talked about choosing mathematics because they saw it as keeping open their career options. Indeed, one of the students quoted above who had originally wanted to do law still had this mainly in mind:

> *"I'm still intending to go into law by doing a conversion course at the end of my degree but I'm still open to the idea of a career in maybe finance or something as well."*

Others mentioned the range of career options, but there appeared to be some ignorance about what these actually were. The following exchange shows students trying and failing to come up with any examples except finance and teaching jobs:

> *Student 1: The general view of maths, if you're going to study maths is if you take a maths degree, become a maths teacher. But it's like, it's far from the truth because you can go into finance…*
>
> *Student 2: So many things.*
>
> *Student 1: … banking, so many things you can go into, it's not just maths, maths teacher.*
>
> *Student 3: Pretty much do anything.*
>
> *Student 2: Yeah.*

Another was clear that although the message that 'maths opens career doors' has been stated loudly and clearly, some still have little idea what these are:

> *Interviewer: …so do you have a sense of what else you can do with a maths degree?*
>
> *Student 1: No, not really.*
>
> *Student 2: Not really, we keep being told that maths is a great subject to have a degree in because it opens so many doors, but I don't really know what those doors are.*

Nevertheless, students do talk about the career opportunities, in more general terms that they have heard that maths graduates are highly valued, and about the subject being seen as prestigious. This is cited both in terms of career opportunities, including in relation to other subjects, personal challenge and in relation to fees:

> *Student 1: I see it as something which is prestigious and I feel that getting a degree in maths is a lot more beneficial in today's world and that's my reason for…*
>
> *Interviewer: What, in terms of the sort of career you might take up and that sort of…?*
>
> *Student 1: Yeah. And not just that, but you know, I also realise that there are some you know, new discoveries to be made, and I'm thinking…*
>
> *Student 2: He's thinking he's up for it.*
>
> *Student 1: … if I'm lucky.*

…

Student 3: Well as [student 1] said, it's seen as prestigious isn't it? And with I think, the government wants fifty percent of young people to go into further education. So lot of people going…

Interviewer: Yeah, moving towards that, yeah.

Student 3: … lot of people out there with degrees, so maths degree stands out head and shoulders over other ones I could name.

Student 3: Also with education becoming three thousand pounds a year, you want to do something good.

Student 1: Get the most out of it.

Student 3: Spend nine grand, coming out not knowing what to do, not being able to do anything.

By way of summary, Figure 3 shows the results when we asked students, in the questionnaire, to say whether a range of given statements were important in their decision to study mathematics. The top three reasons viewed as very important are related to the student's ability and enjoyment of the subject, the next two highly rated statements are related to the range of career options and the potential earnings from them.

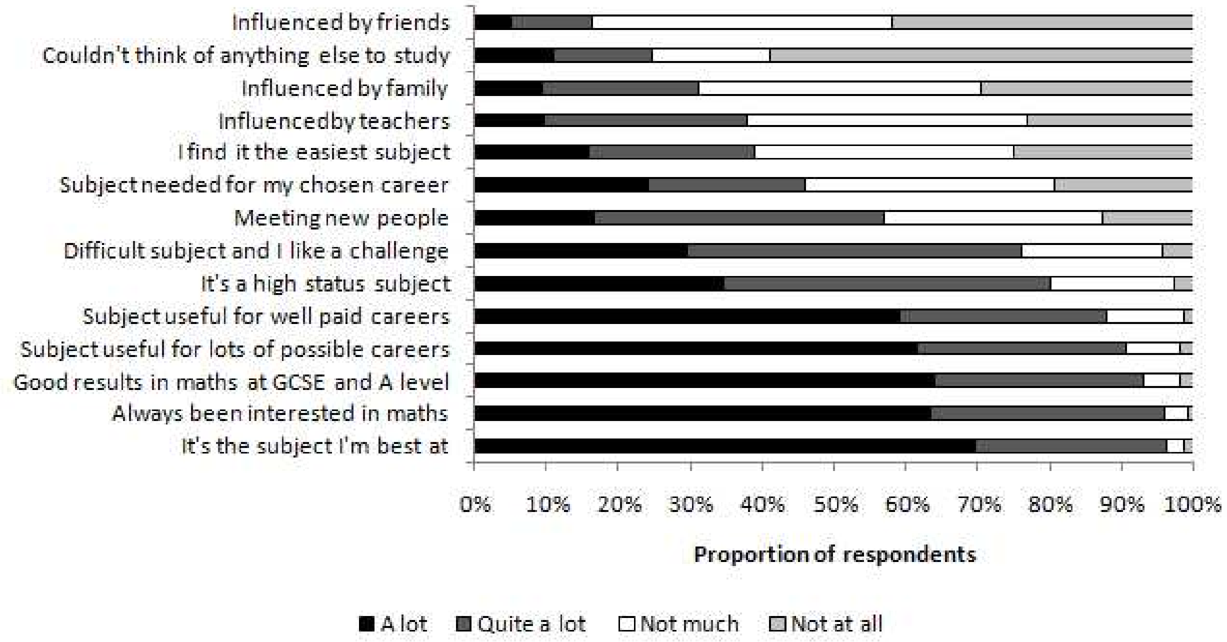

Figure 3:
Proportion of respondents who said that these reasons for studying maths were very, quite, not very or not at all important to them. Number of respondents 211-217.

Figure 4 shows when students made the decision to study maths at university. Inevitably, the highest proportion of students make a decision when the UCAS process begins, but we note that a substantial number make decisions earlier in their school careers which may inform outreach work. More interestingly for mathematics lecturers, there is a substantial minority – around 11% - who make their decision after getting A level results. This may partly explain what some lecturers describe as students with a relatively weak interest in the subject.

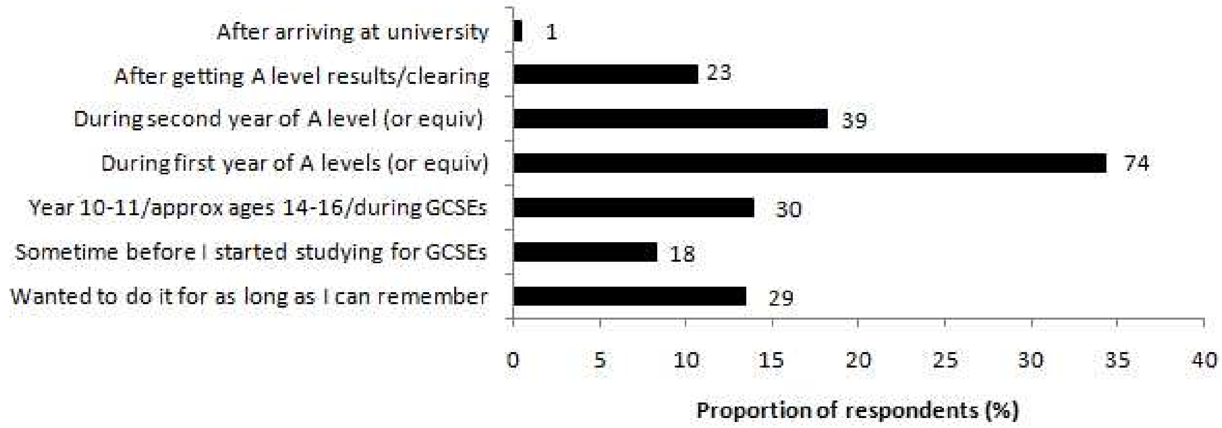

Figure 4: Student responses to the equation "When did you decide you wanted to study maths at university". Number of respondents 214.

The picture that emerges, then, from the student data does not really match the quote with which we ended the preceding section; the majority of our students start their courses positive about the subject and with a positive desire to continue their studies in it, although it is certainly true that they have a mixture of motivations and are not all passionate about the subject. One colleague neatly summed up the range of reasons, saying

> *"Students come to do maths for a wide variety of reasons as far as I can tell. Some just liked the subject when they were doing 'A' Level, they come to university because it's the next thing to do and maths seemed to be the thing to do. Some people perceive maths as being a good degree 'cause it's numerate and has a potential to lead onto good jobs at the end of it, some come thinking I'm gonna be an accountant and maths is something I can do for three years and that looks like a good, good route into it to be an accountant, though I doubt how much of their maths degree they'll use to learn accountancy. Some really, I think, come thinking you know if they might want to be an academic, but I think that's a very small handful of students, but they are there and you can identify them. So yeah, all kinds of reasons... Some end up on the maths degree because they couldn't get into another degree."*

However, the staff view certainly includes a feeling from some colleagues that students ought to be more motivated by the subject itself – that they should be more like us, perhaps. Particularly at the university in this study which offers a variety of 'Maths with…' options there were a number of staff who seemed frustrated to be teaching students who they felt would rather be doing something else.

> *"When I was a student, students chose mathematics or physics because they were good at it. Maths here is not anything you choose because you're good at it. It's a negative choice. You're doing it because you're least bad at it in high school. You're doing it because you can't get into business school and we offer Maths with Finance, Maths with Business. Something like that. So they get the sort of prestigious second part to that degree title by being here."*

Whilst there are undoubtedly students in this colleague's institution for whom this caricature is broadly accurate, the evidence does not support the blanket assertion that suggests this is the only reason (or even the main reason). Perhaps a more accurate picture is painted by someone at the same institution who said:

> *"I get the image from quite a lot of them is that they're, they're wanting to do a degree and they're not very sure really what subject they would like to do a degree in and they're good at maths so they decide to try for a maths degree."*

Since this is true for some students, we raise three questions that staff should perhaps ask themselves. Firstly, if the mathematics community as a whole is trying to send out precisely the message that maths is a good subject for a wide range of future career options, are the faculty body actually happy with the resulting influx of students motivated more by future careers than by the subject? Secondly, if some of us are frustrated with the student intake, how is this likely to manifest itself in the way we treat our students and what impact is it likely to have on their enthusiasm, confidence and performance? Thirdly, if it is true that a substantial proportion of students are here primarily for a qualification with good career prospects rather than a love of the subject, then which is the most important part of our curriculum content: team building and group working, say, or Zorn's lemma or the Cantor Set (however fascinating these may be)?

5 Career aspirations

In our induction-week questionnaire, we asked students 'Have you got any plans for a career when you have finished your degree?' Of the students who answered this question (216), only 43.1% said they had any plans. We find this unsurprising, from various perspectives, including considering what is on the mind of an 18 year just arrived at university, the fact that mathematics has no obvious associated vocational career, and - as already stated by the students - mathematics is viewed as a degree course which keeps open your options rather than shutting them down. It perhaps is therefore more likely to appeal to students who want to defer a career decision.

> *Interviewer: How much thought have you given to what happens [after graduation]?*
>
> *Student: Not a lot really. I just concentrate on trying to get through the course. Like getting through into next year and then trying to think…*

For those students who said they did have some career plan, we asked them what this was. As with our previous open-ended questions, any categorisation of their responses is necessarily imprecise, with some students giving more than one answer and some not really giving an answer at all. A rough categorisation is shown in Table 4.

Financial sector			**61**	**(67.8%)**
• 'Finance' – detail unspecified	30	(33.3%)		
• Accountancy	16	(17.8%)		
• Banking	16	(17.8%)		
• Actuary	11	(12.2%)		
• Insurance	2	(2.2%)		
• Stock market	2	(2.2%)		
Teaching			**18**	**(20.0%)**
Business			**5**	**(5.6%)**
• Management	4	(4.4%)		
• Self-employment/own business	1	(1.1%)		
Further study/research/scientific or mathematical jobs			**7**	**(7.8%)**
• Scientific/mathematical careers or further study in maths/maths related subject	3	(3.3%)		
• Further study in non-maths subject	4	(4.4%)		
Answer not specifying a career			**7**	**(7.8%)**
• High earning	6	(6.7%)		
• Other	1	(1.1%)		

Table 4:
Career plans of students at induction. The table shows the number of times each category was cited and the proportion of students who cited this category as a percentage (1dp) of the total number of respondents (90). Because some students gave more than one reason, the percentages shown sum to more than 100.

A number of points are worth noting. Firstly, this survey was done before the so-called credit crunch; it is not clear whether adverse publicity for the financial and banking sector is likely to either change our students' aspirations, or indeed adversely impact upon the number of applications to study maths.

Secondly, although students seem to have received a message that mathematics is a subject which leads to a wide range of careers, their aspirations are overwhelmingly leaning towards the two traditional destinations of finance and teaching. It is not clear from this whether this is simply their choice at this stage, or whether they have a limited grasp of what other opportunities there may be, but the interview quotes given earlier in section 4 suggest that for some at least, it is the latter.

We have noted earlier that slightly less than half of the students surveyed said they had any plans at all at this stage. To that we can now add a proportion of these whose plans are not, at this stage, anything to do with a specific career, but rather an overall expectation of 'a good job' or 'something that pays well'. Further, even those who gave more indication of their future job plans were often rather vague, saying things like 'I'm not sure, maybe something financial'. In other words, even those who have plans are not necessarily very committed to them.

A similar picture emerges from the interviews with students about their future career plans; namely that few have any definite ideas at an early stage in their university life, and as discussed in section 4 many choose maths partly because they believe it keeps open their career choices. (This is particularly true of the school-leaver entrant to university, whom we are considering primarily in this paper. The picture for mature students is somewhat different – see [2] for more discussion of this.) At best they have a vague idea:

> *Interviewer: Do you… how much have you thought about what you might do once you finish a degree? Or have you not looked further than the next three years?*
>
> *Student 1: It's been difficult.*
>
> *Student 2:To be honest the first thing I'm worried about is how much debt I'm gonna be in after the three or four years. I have sort of looked… I have sort of looked beyond, but not beyond accounting, teaching, maybe going on to do a Masters, PhD, I don't know.*
>
> *Student 1: What I found is that a lot of things like for example internships that might, would make me consider a career in, say for a certain company, don't really come into play until after the second year. So, in which case that sort of stopped me thinking about it for a while.*
>
> *Interviewer: Right. So that wasn't part of what drove you to choose maths as a degree then?*
>
> *Student 1: No.*

Finally we note how few of these career plans directly involve advanced mathematical ideas that might be traditional subjects in many of our courses. How many students expect to need to know about Relativity, Fluid Dynamics, or Combinatorics? This is not to suggest that these topics have no place on a mathematics course – rather as a wake-up call that we should take care to consider carefully which topics are appropriate, and why we should include them. This topic is considered in more detail in [4].

Of course, what students may think about career plans at age 18 is not the same as what they eventually do when they graduate. For discussion of actual student destinations please see [5].

6 The million dollar question

In our second survey, we asked students to tell us whether, with the benefit of hindsight, they would have made the same choice about the course of study; whether they would have chosen a different mathematical course (eg opting for combined honours rather than single honours maths) or a non-mathematical course; and whether they would have gone to the same university. The results are summarised in Table 5.

<table>
<tr><th rowspan="2"></th><th colspan="2">Mathematical course</th><th rowspan="2">Non-mathematical course</th><th rowspan="2">Total: maths or non-maths courses</th></tr>
<tr><th>Same course</th><th>Different course</th></tr>
<tr><td rowspan="2">Same university</td><td>64
(60.4%)</td><td>15
(14,2%)</td><td rowspan="2">7
(6.6%)</td><td rowspan="2">86
(81.1%)</td></tr>
<tr><td colspan="2">Total: 79
(74.5%)</td></tr>
<tr><td>Different university</td><td colspan="2">13
(12.3%)</td><td>5
(4.7%)</td><td>18
(17.0%)</td></tr>
<tr><td>Total: Same or different universities</td><td colspan="2">92
(86.8%)</td><td>12
(11.3%)</td><td>104
(98.1%)</td></tr>
<tr><td>No university</td><td colspan="4">2
(1.9%)</td></tr>
</table>

Table 5: Number of students who said they would choose the same or different course, at the same or a different university.

Almost 87% would still choose a mathematical course, and about 81% would choose the same university. However, only 60% would choose the same course and the same university. Whilst it is hard to speculate on what proportion is ‘good enough’ (and we have no comparative data for other subjects), staff responsible for our undergraduate courses might be disappointed that 4 out of 10 students would wish to have made different choices when they were coming to university. A fuller discussion of the reasons why students are satisfied or dissatisfied with their course is contained in many of the articles produced by the authors; see for example [1] for an overview of the main issues raised by students.

We would hope that improved information about choices (for example, aided by the Maths at University booklet [6]) and continued improvements in undergraduate provision might increase the proportion who are content with the choices they made.

7 Where did they get info?

We asked students to tell us where they got information about their university choices. The results are shown in Figure 5. It is no surprise that this e-generation turn first to the web, with over 80% citing this as very or quite important. Next in popularity was their school or college and the teachers in it - confirming that outreach work in schools is not just about influencing students directly, but an opportunity to influence the people to whom future generations of potential students turn for advice.

Once again, we hope in future that our new booklet Maths at University [6] might improve students’ decision making process by prompting them to ask questions which are particularly appropriate to them.

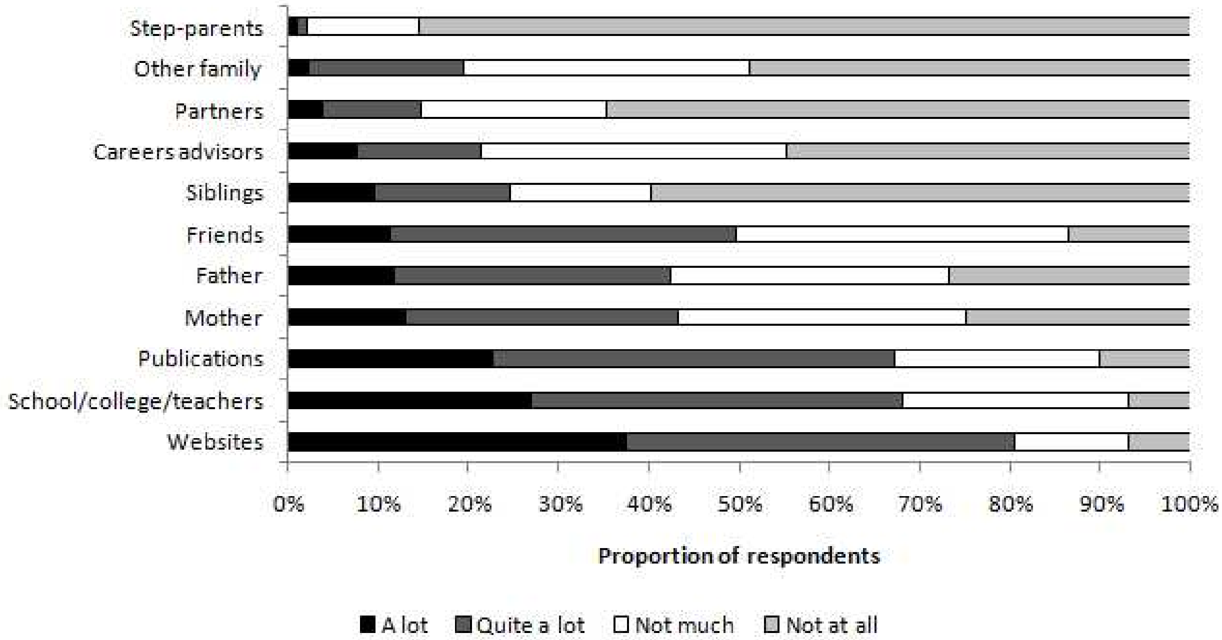

Figure 5:
Proportion of respondents who said they used these sources of information when choosing a university. Number of respondents 219-222.

8 Summary and discussion

What emerges from both the questionnaire and interview data presented above could be summarised as follows:

- The student body is diverse. Our students include those who are fascinated by the subject through to those with more ambivalence towards it. Staff need to recognise that the majority of students may not (yet!) share their passion for mathematics; conversely we need to take care that frustration with the less motivated students does not blind us to the reality that most students do arrive with a positive attitude towards the subject.
- For the vast majority of students, the primary motivation in coming to university is to enhance their future career prospects. The statement 'I need a degree to get a good job' was rated as very or quite important in their decision by 93% of students. For university staff, with, perhaps, more liberal attitudes to the value of higher education, a passion for the subject, and a secure job already, this is a reality which can easily be forgotten. Recalling that this is the students' primary concern reinforces the role of employability and key graduate skills within the HE maths curriculum. See for example [7] for a discussion of employability skills.
- Whilst students are primarily concerned with their future employability, relatively few of them have any clear idea of their future plans. Indeed, it would appear that a decision to study maths is in many cases influenced by a belief that a mathematics degree opens a wide range of career doors, and is therefore a good degree for those who want to keep their options open.
- Students' knowledge of what careers they might follow appears to be somewhat limited. Both those with future plans, and those without, mention (primarily) finance related jobs, and teaching - the traditional destinations. This is somewhat surprising given that they also state that they believe mathematics graduates can be employed in a wide range of jobs. We note that, perhaps, the work of the Maths Careers website [8] and outreach work may improve this position in time. However, this lack of current knowledge about career options might point to the need, within mathematics courses, for some help in improving students' knowledge of the options open to them - see for example [5] for a discussion of careers awareness within the curriculum.
- Very few students start with the intention of doing a job which we would describe as heavily mathematical. Indeed, destination data [5] confirms that the majority of our students do not in future use advanced mathematical ideas in their work. They do, however, often do jobs which require the key mathematical skills and attitudes (eg logical thinking etc) or lower level mathematical skills (eg in teaching to A level standard) or general quantitative skills such as effective use of spreadsheets for a variety of tasks. The question for mathematics academics then must surely be: what curriculum content will allow the students to develop these skills best, whilst still including sufficient advanced mathematical content for the future research mathematicians? This is a theme which is discussed further in [3].

We end with a statement which is perhaps obvious, but which is nevertheless worth reiterating: mathematics students are people first, and mathematicians second. As such, they come with a wide range of aspirations, needs and motivations. In the interests of achieving graduates who leave feeling they have had a positive experience of mathematical study at university, we must aim to understand these motivations and take them into account alongside other more mathematical considerations when we design our courses and programmes.

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2.2 *Location location location*

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1 Introduction

When students are applying for university, numerous factors are at play which affect their choice of subject, specific course, town or city, university – or indeed whether to go to university at all.

In [1] we have discussed the reasons students choose to study maths at university. In this paper we consider the decision they make about the university to study at. On the face of it, this may seem to be beyond the scope of the More Maths Grads project; provided students choose to study maths, why should we care which institution they study at?

In fact, whilst it is true that we are concerned mainly with the overall number of maths students, rather than where they study, there are nevertheless a number of reasons why a discussion about location is worthwhile.

Firstly, in [1] we presented evidence that, for some students, the decision to study maths is relatively weak; that is to say they could easily be persuaded away to another subject. Thus, it is possible that if a mathematics course is not available in the location that the student desires, he or she may decide to study a different subject instead.

Secondly, understanding how students make decisions and the factors that influence them has potential impact on future outreach work with schools aimed at promoting mathematical study.

Thirdly, although this makes little difference to the overall number of mathematics graduates, we anticipate that the question of where students choose to study will be of interest to individual departments and admissions tutors.

2 Student decisions about where to study

What factors influence student decisions about where to study? Firstly, let us present some findings from students who are studying mathematics. In section 7 we shall consider the question of how to gain information about potential students who have chosen not to study mathematics at university.

As part of this project, we surveyed over 200 standard-entry (that is to say, roughly aged under 20 at induction) students at diverse institutions during their induction week. We asked them, in an open-ended question, to tell us the most important reason why they had chosen this university. Because of the open-ended nature of the question, categorising their answers is inexact, but Table 1 gives some indication of the reasons they gave.

Reputation			**91**	**(42.5%)**
• University has a good reputation	35	(16.4%)		
• Maths here has a good reputation	32	(15.0%)		
• A good reputation (did not specify university or maths)	25	(11.7%)		
• League tables	4	(1.9%)		
• 'The place with the best reputation that would take me'	9	(4.2%)		
Life beyond mathematics			**67**	**(31.3%)**
• The city	46	(22.0%)		
• Sport/social life/night life	16	(7.5%)		
• Campus university	11	(5.1%)		
• Family and friends locally	8	(3.7%)		
Course-related			**40**	**(18.7%)**
• The right course for me	36	(16.8%)		
• Chance to study abroad/year in industry	6	(2.8%)		
Distance from home			**33**	**(15.4%)**
• Near enough to live at home	11	(5.1%)		
• Near enough to home (but not living there)	17	(7.9%)		
• Far enough away but not too far from home	2	(0.9%)		
• Far enough from home	3	(1.4%)		
Atmosphere/friendliness			**32**	**(15.0%)**
• 'I liked the atmosphere'	18	(8.4%)		
• Friendly staff	13	(6.1%)		
• Influenced by the open day	5	(2.3%)		
Miscellany			**20**	**(9.3%)**
• Facilities (eg prayer room)	3	(1.4%)		
• Miscellaneous	17	(7.9%)		

Table 1: Most important reason for choosing this university. The table shows the number of times each category was cited and the proportion of students who cited this category as a percentage (1dp) of the total number of respondents (214). Because some students gave more than one reason, the percentages do not sum to 100.

The students clearly have a wide range of reasons for choosing their place of study, some of which are well beyond the influence of the mathematics staff.

Firstly, the reputation of the department and university is key to many students' decisions – with a sense that they are aiming for the university with the 'best' reputation, to which they can gain entry. We might speculate that students' ideas of 'reputation' are often synonymous with high entry requirements. If this is the case there is a self-fulfilling cycle which is quite independent of any objective measure of the university's provision per se: high entry requirements create a good reputation, which in turn makes the course popular, which allows the department to have high entry requirements. Indeed, this point is made succinctly by [2], saying

> *"There is a widespread, and probably accurate, perception that certificates (degrees) from some universities are more valuable in the job market than others - i.e. there is a hierarchy of esteem. That may be regrettable, and to some extent the effects may be deleterious, but it is a reality. By and large - not in all cases but by and large - students will tend to apply for the most prestigious institutions that they think they are capable of gaining admission to, institutions select the most able students that apply, and employers, believing that in so doing they will be recruiting the most able, favour students from those institutions, thereby creating a vicious (or virtuous) circle that perpetuates the hierarchy of esteem."*

The same author suggests that this situation may change, both because of increased numbers of students studying at home, and the increased availability of various aspects of university experience - eg the plethora of league tables, and the National Student Survey [3] results. The latter is particularly interesting in this respect, in that the scores obtained by mathematics departments (average unweighted score across the 22 NSS questions) is not positively correlated with entry requirements for these courses (in fact, there is a weak inverse correlation, as shown in Figure 1).

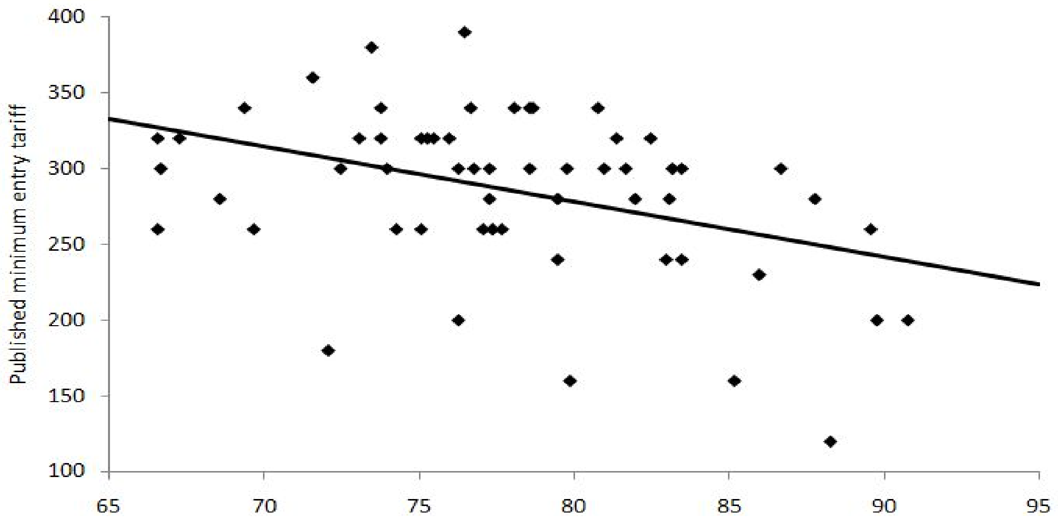

Figure 1:
Published minimum entry tariff from [4] against average National Student Survey score [3], where both are available (r^2 = 0.16).

In other words, the popularity of courses with high entry requirements is not related to the existing students' view of the quality of their provision. University departments with relatively low tariffs and high NSS scores may hope that these data will, in time, result in a shift in students' perceptions about what constitutes a 'good' university, but we doubt that this should be overstated; for the reasons given above, it seems likely that

> *"these developments should not be exaggerated. If it is indeed the case that a degree from one university is more valuable in the job market than another then it is entirely rational that students would prefer to obtain a degree from that university, whatever the facts about the quality of provision. It is difficult to see how this pattern can be broken (if indeed that is thought desirable)." [2]*

Separate from the 'reputation' of a course or university, students may be influenced by the course content or structure. A number of students - roughly 1 in 5 - did cite this as their primary reason. We might argue that - in a more informed and rational world - the specifics of the course should be a more important factor in students' decisions; indeed it seems likely that getting the right student onto the right course would bring significant improvements in enjoyment and performance for students (and associated improvements in student retention and job satisfaction for staff). As staff, we may know that there are significant differences (and these are recognised as valid - indeed vital - by the Mathematics, Statistics and Operational Research Benchmark [5]) but students are unlikely to fully appreciate the differences between courses, perhaps assuming that most degree programmes that share the G100 code would be broadly similar. With this in mind, the More Maths Grads project has produced a new booklet [6] for potential students of mathematics which aims to help them discern the differences between courses and make an informed decision about which universities to apply to. However, the preceding discussion about the relative importance of a university course's reputation will still apply.

The second most quoted aspect influencing student decisions about location is what we have termed in Table 1 'life beyond mathematics'. That is to say, that over 30% of students cite as their primary reason something which has nothing to do with either the course, or the university reputation. Most common amongst these was that they wanted to be in a specific city (this was most often the case for students studying in London, but was also cited by students in other places).

Around 15% of students were influenced by their experience or expectation of the university or city, talking somewhat intangibly about the 'atmosphere', or saying that they found the staff friendly when they visited. Clearly the efforts put into open days by universities can have an effect on many students (and we might speculate that, whilst only 15% give this as a positive reason for applying, had they found staff unfriendly then the proportion whose decision would be negatively affected would be much greater).

Within our sample around 15% say that the distance between university and their parental home was a primary reason for their decision. Students have a variety of views on this, taking in 'close enough to live at home', 'near enough to go home at weekends but far enough that I have to live away' and 'far enough away'. In this sample, 1 in 20 say that being able to live at home was important. However, 16% were living with their parents. Recall that this survey includes only non-mature students; we anticipate that the proportion of mature students who want to study at their local university would be much higher. The question of whether a desire or need to stay at home to study affects particular groups of students disproportionately is something we shall return to below in Section 4.

We also asked students to rate a series of statements as very, quite, not very or not at all important in their decision. This gives a broader picture of their range of factors influencing their decision, in the sense that they were not constrained to choose just one reason, but is clearly affected by the choice of statements we gave them. The results are shown in Figure 2.

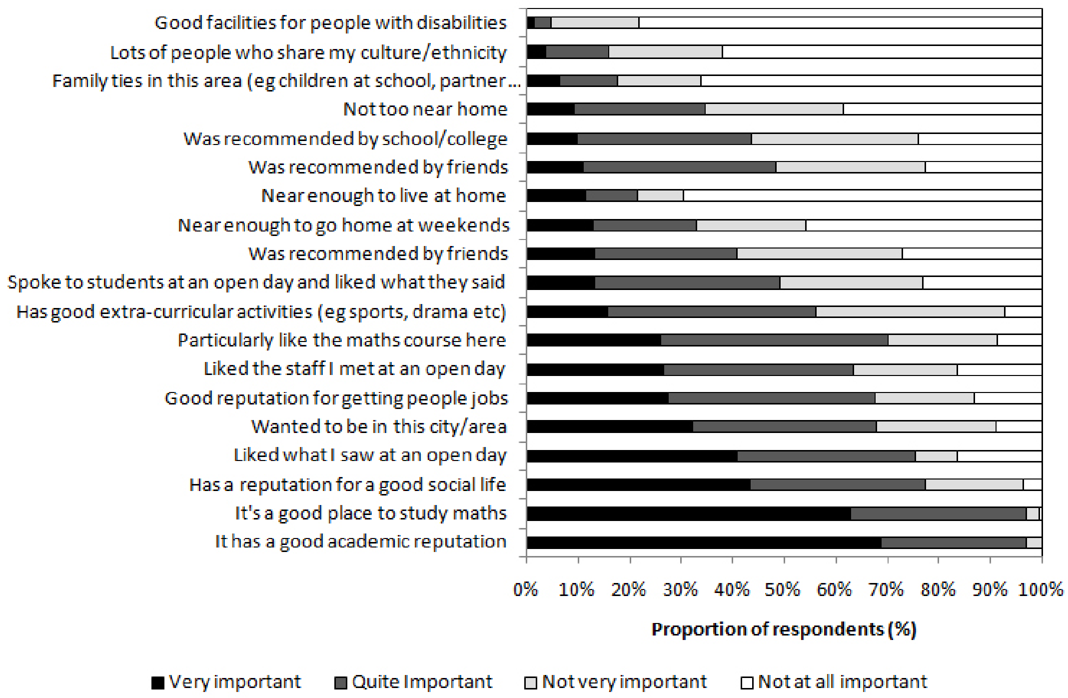

Figure 2:
Proportion of students who said the given reason was very, quite, not very or not at all important in their decision to study at a particular university. Number of respondents 216-222 depending on the statement.

The results broadly follow the trends discussed already in relation to what students cited as their primary reason, although in this format we can see what is perhaps obvious – namely that a range of factors influence students. We note that academic reputation, social life, wider surroundings, open days, employability and first impressions of staff all rate more highly than the specifics of a particular mathematics course. Distance from home is important for fewer students, although still rated as very important by a significant minority.

3 Availability of mathematics courses in the UK

A search of the UCAS website [7] by course code G100 reveals that, starting in 2010, there are 64 courses at 63 universities offering a single honours mathematics degree. Searching by subject and selecting 'mathematics on its own as a single subject' gives over 450 courses, many of which - rather confusingly - are combined honours, or subjects which, whilst mathematical in nature, do not contain maths, stats or operational research in the title. Despite this increased range of broadly mathematical courses, the number of universities which offer them increases only slightly, to 67.

At first glance, this would seem to suggest a wide choice for potential students whatever the particular factors which are most important to them (although we should note, of course, that only the very best students could gain entry to any university). In fact, further inspection reveals that the universities in question which offer the G100 course are in just 45 individual towns and cities. What is more, these are not evenly spread across the United Kingdom. Table 2 shows the number of universities and the number of towns/cities with a G100 course, alongside population estimates from 2002.

	Universities with a G100 course	**Towns/cities** with a G100 course	**Population** (thousands) *estimated 2002* [8]	**Population per G100 course** (thousands)
Scotland	8	6	5065	633
Wales	4	4	2923	731
North East	3	2	2512	837
West Midlands	6	4	5303	884
South East	9	7	8028	892
London	8	1	7355	919
London and South East Combined	17	8	15383	905
North West	7	6	6771	967
South West	5	4	4958	992
East Midlands	4	3	4214	1054
Yorkshire and the Humber	4	3	4977	1244
East of England	4	4	5427	1357
Northern Ireland	1	1	1697	1697

Table 2:
Number of universities and towns or cities with a G100 mathematics course, by country or English Government Office Region (GOR), alongside population estimates (2002).

We include in Table 2 the population per G100 course in the region. This is not because population density per course is necessarily a key indicator, but rather than it demonstrates that the differences in the number of universities offering mathematics in a particular region is not simply a by-product of different populations in that region.

This geographical spread of mathematics courses is described in rather more detail by Nigel Steele's 2007 report, Keeping HE Maths where it Counts [4]. He discusses the availability of mathematics courses in the light of the fact that 'five mathematics departments have closed since 1995' and 'a number' of departmental amalgamations and university reorganisations have also resulted in a decline in undergraduate provision. In particular, Steele analyses the geographical spread of courses and says

> *"an analysis of the mathematics course provision based on A-level achievement in the UK shows significant areas of the UK where there is no 'broader-entry' course provision. Course provision at all entry levels is sparse in the east of England, and absent in North Wales."*

Steele's euphemism, 'broader-entry' is used to refer to courses where the entry requirements are that students may be asked for up to a grade B in A level maths; in other words we are not only considering very low entry requirements. He observes that

> *"the picture is bleak in terms of 'broader-entry' courses in the whole of Eastern England, Wales and in the central and western parts of southern England."*

He also notes that where there is a 'mathematical desert' this does not necessarily correspond to areas of the country with low population; he points for example to closures of courses in Hull, Bradford and Sunderland as contributing to problems in the east of England.

We note that since Steele's report, there have been no further closures of G100 mathematics courses, nor any new courses appearing, and so his analysis remains as valid now as it was in 2007.

4 Loss of student opportunity

Steele is concerned with two particular impacts of the geographical spread: the impact on the local area, (which we consider in section 5), and the loss of opportunity for students, particularly those who, for one reason or another, want to live at home whilst studying full time. He notes that this is a particular issue in relation to the widening participation agenda, saying

> *"experience indicates that a significant number of these are from backgrounds with no previous experience of HE."*

Thus there are numerous questions which might concern us. Firstly, does the absence of a mathematics course in a student's preferred location actually put them off studying maths? If so, how many potential students are affected? Is Steele's assertion – an expectation we and many of our colleagues share - about certain types of student being particularly affected true?

Trying to obtain information about this topic is particularly difficult. We have, of course, access to students who have come to university; particularly within this project we have access to students at four universities who have chosen to study maths. But these students have – self-evidently – not been deterred from coming to university. We have rather less access to students who have chosen to study a different subject, or those who have considered coming to university but decided in the end not to. Thus we have no clear means of identifying whether such students really exist, how many of them there are, or what were the key factors affecting their decision. (In the final section of this paper, we consider how this problem might be addressed in the future.)

What we can do then is skirt rather perilously around the edge of this topic, talking to students who have come to university to do maths, talking to maths teachers in regions where there is no local undergraduate mathematics course, considering the data we have from students who have come to university, and speculating on how this information might be extrapolated to a more general population of potential students.

Firstly then, of our sample of over 200 standard-entry students at three universities, 16% were living with their parents whilst studying at home. We note a massive variation between the three universities (3% at one university, 59% at another), and that at the latter university our survey covered around 30% of the intake but at the former the survey covered almost all students. We do recognise that it would be foolish to assume that this 16% figure could be considered accurate in relation to the whole student population, but what it does suggest is that the proportion who want to live at home is certainly not insignificant.

Secondly, this figure represents the number of students who are still living with their parents. It excludes those who, whilst living away from their parents, nevertheless are studying close to their family home. As such it is perhaps an underestimate of the number of students for whom the presence of a 'local' university is important.

Next, we consider whether, as discussed above, groups which are often under-represented in HE are more or less likely to live with their parents whilst studying. Table 3 shows the proportion of students who are living at home according to various categories, namely the highest educational qualification of their most educated parent, their parents' occupation, their gender, and their ethnicity.

Highest parental qualification †		
University educated	11.5%	(11/96)
A level or GCSE	18.8%	(15/80)
No qualifications	26.7%	(4/15)
Average ††	15.7%	(30/191)
Parents' Occupation ‡		
Managers and Senior Officials	10.5%	(4/38)
Professional Occupations	7.7%	(5/65)
Associate Professional and Technical Occupations	6.7%	(1/15)
Administrative and Secretarial Occupations	25.0%	(3/12)
Skilled Trades, Personal Service, Sales and Customer Service, Process, Plant and Machine Operatives, Elementary Occupations, not in paid employment	42.1%	(8/19)
Average	14.1%	(21/149)
Gender		
Male	15.2%	(16/105)
Female	17.7%	(17/96)
Average	16.4%	(33/201)
Ethnicity		
White British	9.0%	(12/134)
All other ethnic groups combined	32.3%	(21/65)
Average	16.6%	(33/199)

Notes:

† As reported by students, highest level qualification of parents, step-parents, or other primary carer

‡ As reported by students and categorised by the authors, according to [9], as far as possible. Insufficient data available to give full socio-economic grouping. Table shows occupational group of the parent, step-parent or primary carer with highest occupational grouping.

†† Because there was insufficient data to identify parental qualification, occupation, and ethnicity on all students, the total number of respondents and the averages vary. The overall average of students living with their parents (where we have data to identify this) is 16.4% (33/201)

Table 3:
Proportion of students who are living with their parents whilst studying, by parental qualification, parental occupation, gender and ethnicity (and in brackets, number living with parents/total number in this category).

Once again, given the unrepresentative sample, we do not suggest here that the absolute proportions quoted can be assumed to hold across the general student population. However, the interesting point is in the comparison across different groups. In respect of parental occupation, and ethnicity there is strong evidence of the expected results discussed above and in [4]. To choose an example in each case, according to these data:

- a student whose parents work in the SOC2000 [9] categories 5 to 8 (skilled trades, personal services, sales etc) or who are not in paid employment is five times more likely to live at home than a student with a parent who is in categories 1 to 3 (managers, professionals or associates, technical occupations etc) (42.1% against 8.5%, significant at 0.1% level according to the Fisher Exact test);
- students who describes their ethnicity as any group other than 'white British' are more than 3 times as likely to stay at home than students who describe themselves as 'white British' (significant at 0.01% level, Fisher Exact test).

There is weaker evidence about a correlation between students' willingness to travel for university and their parents' experience of higher education. A student with no university-educated parents is almost twice as likely to stay at home during their own university education, compared to a student with at least one parent who went to university (22.3% stay at home compared to 11.5%, $p = 0.077$ with the Fisher Exact test).

We note one piece of good news here, namely that there is relatively little difference between male and female students in our sample, and that difference we found is not significant ($p = 0.7$).

Our survey data above do not include, regrettably, information about mature students. Given that they are more likely to be settled or to have family commitments, we would anticipate that they are far more likely to want to stay local. There is strong evidence that this is the case; for a fuller discussion of the issues affecting adult returners to mathematics, see [10]. For the sake of this paper, we choose to focus primarily on the standard-entry student, whilst noting that the issues are even more pronounced when mature students are included.

In the case of the students in our survey, they – clearly – managed to find a university which suited them; whatever their views on location, these were not a sufficient deterrent to prevent them from studying mathematics or going to university. The question now is, are there students who, wanting to live at home whilst studying full time, and finding no local university to which they can gain entry, decide to abandon mathematics in favour of a different subject or decide not to go to university at all.

As discussed previously, accessing potential students in this position is not straightforward. Assuming that they exist at all, the one thing we can be sure of is that we will not find them in a mathematics department, but it is not clear where we should look for them. We therefore tried two approaches. Firstly, we targetted schools and teachers in one of the regions identified as having limited access to any mathematics course, and certainly to the 'broader-entry' courses, namely the area around the Humber estuary, inviting them to talk to us about whether they saw this as a problem for their students. We were expecting that, if this is a problem for potential mathematicians in these areas, the teachers might be able to supply anecdotal evidence of individual students for whom lack of local provision had prevented them from studying maths. Secondly, we talked to students at our own institution who were still living with their parents, asking them the hypothetical question 'if you had not found a university which would admit you close enough to home, what would you have done?'

Of the maths teachers we spoke to, roughly half said that they could not think of any occasion when this had been a problem. Others expressed a different view. One who teaches only to Year 11 said that even at this stage, some students already believed that they wanted to go to university locally and were aware already that this precluded them from doing mathematics. Generally speaking the reason was financial. Because he didn't teach beyond Y11, he had no knowledge of whether they maintained this stance; in fact, he said he hopes they 'grow out of it' during their sixth form.

Staff in one sixth-form college were very keen to discuss this with us, and having discussed it at their staff meeting, contacted us to say, very adamantly, that this is a problem. The head of department described how a 'high proportion' of students in Hull – higher than from other areas where he has worked – want to study from home, for a variety of social and financial reasons. He talked about the area being relatively deprived and some students supporting their families at home and therefore being unable to afford to leave. As he put it, the 'lure of staying is big here'.

However, when we asked about whether there were specific students the teacher could identify who had chosen not to do maths as a result, he could not think of any. He talked about how, in practice, a 'very committed, mathematically well qualified staff' persuade students who are keen on maths that if they're good at it, they should do it regardless of having to leave home. They usually go, he said, to York ("we get them the grades they need") which is a distance of approximately 40 miles (driving time about 1 hour) and students either commute, or do leave home but know that they can return easily. We note that York could not be described as a 'broader-entry' course; perhaps it is the case that this teacher wouldn't expect a student with lower A level attainment to go on to study mathematics.

A third teacher reported similarly, that they thought there was a problem, but that this hadn't in fact stopped anyone they could think of from studying maths.

Thus the picture that emerged from teachers was that they either said there was no problem, or they thought there was a problem but when pressed couldn't think of any students where this had in fact dissuaded them from studying maths.

Of course, not all pupils will share their decision making process with teachers; if what the Y11 teacher discussed above is true, then some students will simply reject maths at an early stage and their teachers might never view them as a potential maths undergraduate.

When we spoke to our students who live locally, we asked them about the reasons for that decision, how far they were travelling, and the hypothetical question: if you had not found a local mathematics course, what would you have done?

Whilst some of the students we spoke to lived in the same city already, others were travelling substantial distances to reach us; up to an hour's travelling was not uncommon. The reasons for wanting to stay at home were two-fold: family commitments (for example, dependent parents in poor health) and financial. On the crucial question of what they would have done if they had not found a mathematics course close enough to home, their responses covered several possibilities, namely:

- I would have moved away from home to study maths at a different university
- I would have given up on the idea of going to university
- I would have done a different subject so that I could stay at home.

Finally, we might speculate on one other aspect of this; namely that where departments have closed or are under threat, they usually have a relatively small student intake (if it were otherwise, they would be unlikely to close). Whilst the preceding discussion focuses on local provision, it is also possible that closure of smaller departments might deter some students. One colleague believed that, from discussions with students, there are those – particularly women students – who favoured what he called 'small and friendly' 'more homely' provision rather than the 'macho culture' of the big prestigious university departments. Whether or not this analysis is correct, we can surely agree that diversity of provision is likely to encourage 'more maths grads' more than a small number of big providers.

In summary then, we know that when the opportunity is there, a substantial minority of students would prefer to stay at home to study. There is strong evidence that this is particularly an issue for students who are traditionally under-represented in higher education, ie ethnic minorities, students from lower socio-economic groups, and students whose parents are not university educated. (We could also add that mature students tend to have greater reason to study at their local university.) There are undoubtedly areas in the country with substantial populations but without access to a nearby mathematics course. In these areas, some but by no means all maths teachers believe this is a problem. Some of the students who are studying locally say that without that opportunity, they would not have studied maths at university. However, the limited evidence from teachers might suggest that in reality, faced with this situation, many students are not in the end deterred from studying mathematics. Because of the invisibility of students who have not come to university, or are not studying mathematics, we are unable to quantify – even in the vaguest terms – the size of the problem.

5 Damage to the local community and the mathematical ecosystem

The second potential problem identified by Steele in relation to the mathematical deserts is the impact on the local area, both in terms of the economic loss from the lack of opportunities for research and consultancy, and also from the potential loss of specialist mathematics teachers to local schools. On the latter point, he speculates that the same students who need to stay at home to study might, for similar reasons or through inertia, remain in the area as future teachers. Thus the loss of a mathematics department or course locally may contribute to a lack of specialist teachers in the area, with its consequent reduction in the opportunities for mathematics study in the future.

One colleague who works in a 'broader entry' department also made the point that their course produces a higher proportion of future teachers than was typical from G100 courses; our experience (also of a 'broader-entry' course) would support this idea. Perhaps for students at universities with lower entry requirements, the big-money city jobs are less available to tempt them away from more worthwhile activities!

To this point we would like to add something which three teachers raised with us concerning the disadvantages of the closure of their local university mathematics department. This is that without the local maths faculty, there are fewer opportunities for enrichment activities for their mathematics students. One teacher spoke about 'support' from Hull University mathematics department supplying extra classes, and that this both encouraged student engagement with mathematics but also helped them to expose their pupils to the idea that they might do maths at university.

These two points together illustrate how the presence of a local mathematics department helps to support the local mathematics ecosystem, or rather how its absence might damage it. In effect, the loss of opportunity might not just be felt by those who want study locally, but by a loss of future specialist mathematics teachers and a lack of outreach opportunities, the number of local pupils applying to study mathematics at any university might be reduced.

6 Drivers and barriers to change

Steele considers the economic drivers, including the Research Assessment Exercise, which form the backdrop to decisions about course provision in universities. His analysis suggests that, by and large, broader-entry courses are concentrated in departments which are not research-intensive. He notes that there is some evidence, based on staff age profiles, that these departments are not recruiting new staff, and suggests therefore that the remaining broader-entry courses may be in an even weaker position in the future.

One colleague identified a further pressure on smaller, broader-entry departments which was particularly apparent when there was a shortage of mathematical applicants after the initial effects of Curriculum 2000. Faced with a potential shortage of students (and whatever happens with future demand, it seems likely that there will be occasional fluctuations), departments which normally require high entry requirements can make lower offers to potential students, thus maintaining their own student numbers whilst simultaneously depriving the departments which normally have lower entry requirements of their students. He speculates that the larger department, more used to high-achieving students, may not cater very well to the weaker students, and when overall applications increase will revert to requiring high grades on entry. However, in the meantime, there is a risk that the original broader-entry course will have closed because of lack of numbers, with all the attendant loss of opportunity identified elsewhere in this paper. He does not suggest that the big departments do this in a conscious attempt to drive competition out of business; indeed he describes a friendly relationship with his nearby big department; nevertheless the situation he describes could be thought of as analogous to the situation with supermarkets and local shops, where particularly during a downturn, the big players can protect themselves at the expense of smaller fish.

Steele also notes that the Higher Education Funding Council for England (HEFCE) believes that support for STEM subjects must be 'demand-led' – hence the funding for projects like the More Maths Grads project, and the new HE STEM project [11]. One might consider, however, what happens when demand for mathematics at university increases, either because of these projects or other changes. Increased student numbers make existing departments more secure, but it is much harder to imagine circumstances in which increased demand would result in a new undergraduate mathematics course starting in a university which does not have a mathematics department. Where courses have closed, staff have generally left or been scattered amongst those departments with a remaining need for mathematics teaching, and without the core teaching staff with a subject-specific identity it seems unlikely that increased demand for places will ever result in new courses.

Thus we have a double squeeze on the smaller departments with broader-entry courses; whilst there are economic drivers which might lead to universities closing down mathematics departments, there are few circumstances in which the reverse is likely to happen.

7 Conclusions

Student decisions – both individually and as a group – about location are influenced by a variety of things. For many students, foremost amongst these is the reputation of the university, perhaps measured chiefly by its admission criteria. Since a university with a good reputation therefore receives more applicants, and can therefore maintain high entry requirements, this notion of a 'hierarchy of esteem' may be self-fulfilling quite independently of the actual quality of provision.

It is possible that the introduction of league tables in a variety of forms may introduce some more objective measure into the notion of university reputation, but the extent to which this will happen is not clear.

Making university choices on the basis of the differences between courses is relatively rare. Fewer than 1 in 5 students cite aspects of the course provision as being their primary concern. We argue here that it would be in the interests of both academic staff and, more importantly, future students if we made more efforts to get the right person on the right course. To this end we hope our booklet Maths at University [6] is widely promoted including by admissions tutors, but even then we acknowledge that many potential students are likely to choose their university according to other criteria.

We know that there are some students for whom the ability to live with their parents whilst studying (or in the case of mature students, to study in their existing home town) is important. There is evidence to support the popularly held view that this is particularly the case for students from ethnic minorities, for those from working class backgrounds, and those with no family experience of university education.

We can find only weak evidence that this factor is sufficient to deter many students, but note that identifying students for whom this has been an insurmountable barrier is necessarily difficult. We consider that it may be beneficial, perhaps exploiting the co-operation between different subjects now built into the HE STEM Programme, to commission a study to better understand the extent of this issue. Such a study could perhaps work with students in their sixth-form to understand their decision making process (although we recognise that in working with sixth-formers we are likely to affect the thing we are measuring) or surveying students in universities across the numerate disciplines.

We review the work of Nigel Steele about the geographical availability of mathematics courses, and in particular the 'mathematical deserts' where there is no university course, or no course with lower entry requirements. In particular, we note his findings that the damage is not limited to those students who may be directly deterred from studying maths, but that the loss to the local mathematics ecosystem may be exacerbated by a the loss of future specialist mathematics teachers locally, with the attendant loss of future mathematics applicants from the area to any university. To this we add some evidence from teachers in one of the mathematical deserts that the loss of outreach work when their local university closed its mathematics department reduces the possibility of enrichment activities for maths at school, and exposure of students to the idea of studying maths at university, and that this further damages the possibility of recruitment to study maths for pupils in the area.

We also report Steele's finding that broader-entry courses may be sited in departments which face further economic problems, because they are not research-intensive. He cites a lack of staff recruitment as evidence of potential further closures. To this we add speculation from colleagues about the economic drivers when student numbers fall, and a tendency for bigger departments to survive whilst the smaller players go under. Whilst we hope that in the future demand for mathematics at least stays solid, some fluctuation seems likely and we note that even with increased demand, it is hard to imagine circumstances in which new departments and courses would be created, indeed, we see no mechanism for the creation of new courses in places where the mathematics department has closed. Thus the number of courses and departments can only vary between constant and declining.

In effect, we have a mismatch between the 'public good' of having an active mathematics department available in any area, both in terms of opportunity for students who need to live locally, and in supporting a mathematics ecosystem locally, and the fact that the benefits of this public good are not always high enough to provide an economic incentive for local universities to maintain their existing maths courses, and are extremely unlikely ever to lead to the creation of new courses.

Damage to the local mathematics community could be mitigated in part by extended outreach by universities closest to the mathematical deserts; however, once again, the benefits are too dispersed for it to be easy to make a clear cut financial case for this; successful work often relies on an academic belief in supporting the subject as a whole sometimes in defiance of a cold cost-benefit analysis for the individual department.

In summary, we return to Steele's report. His first recommendation started:

> *"steps need to be taken to ensure that there is an adequate level of provision in mathematics in HE on a sub-regional basis in the UK..."*

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2.3 *The future of Polymaths*

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Introduction

As part of the HE Curriculum strand of the More Maths Grads project [1], we are looking at routes into mathematics for students who have not followed a traditional path from GCSE, to A-level, and directly onto university. One option for students considering a return to mathematics is the Polymaths course, validated by the IMA, and whilst we intend to write more later about other ways into mathematics such as access courses and preparatory years, it seems appropriate to share our examination of Polymaths with IMA members first and invite your views at this stage.

In this article we first explain what Polymaths is and consider some of the barriers to expanding the Polymaths programme. We then consider various options for what should be done with Polymaths in the future.

Polymaths then and now

Polymaths was established in the 1970s as a collaborative effort by a number of Polytechnics (hence the name), and is a part-time one-year course to roughly A-level standard. Over the subsequent years fewer and fewer HEIs offered the course, until today only the University of Bolton [2] and Liverpool John Moores University [3] (LJMU) do so. It is not clear whether the decline in the number of institutions running Polymaths was due to lack of demand, or financial considerations, though these are clearly linked and, as we discuss later, we suspect that money is a significant factor.

Over the years Polymaths has been modified slightly to reflect the changing nature of mathematics, particularly the increasing use of technology, with the result that the two courses which remain are similar but not identical; both include modules in calculus, functions and graphs, fundamental maths/algebra, statistics and computing alongside development of key skills. Assessment is via frequent coursework (known as 'objective' and 'periodic' tests), and to pass students must gain 700 marks out of a maximum 1200. In both institutions, students who do not reach the standard required for the IMA Polymaths qualification may be awarded an alternative qualification in the form of an Access award from the Open College Network North West Region (OCNNWR) in the case of Bolton, or a Certificate of Continuing Professional Development at LJMU.

The students' motivations are, of course, varied, and typically include those who hope to gain entry to a maths degree, some who want to gain access to another numerate discipline, some expecting it to be useful to their career, and some who are doing it purely for pleasure. We have no precise data on age or gender, but one student reported the ratio of women to men to be approximately 50:50 with 'a lot of women in their 40s' aiming to become teachers now that their children were old enough. Now there's a demographic the maths community should welcome with open arms!

In both institutions, almost anyone who wants to try the course is allowed to do so. The low cost to students (£60 at one institution, £186 at the other) covers 5 hours teaching per week for a year and all the assessment and materials. There are, therefore, relatively low barriers to students 'giving it a go' and correspondingly, there is a high drop-out rate: roughly half complete it.

Does a Polymaths award guarantee acceptance on a maths degree? The picture is mixed; where admissions tutors know the course already, it seems to provide a route into further study. However, as the number of institutions offering the course has declined, so too has the number of staff who know Polymaths. There is evidence, however, that where applicants talk to admissions tutors about the course content, acceptance onto well-regarded maths degrees is certainly possible. One of the staff involved running a Polymaths course who also teaches on his institution's degree course reports that Polymaths students generally gain Firsts or 2is in the degree; indeed, so confident is he about the standard of Polymaths that he would accept students onto the degree course who had passed only certain Polymaths modules. Having looked at the course content, we would agree that students who complete it successfully should be at least as well prepared as A-level students for many maths degrees. Admissions tutors wanting more detail could look at LJMU's student handbook for details [4].

Polymaths money

At LJMU, student fees for Polymaths are £186. Considering that this includes approximately 150 hours contact time, administration, preparation and assessment, it's not hard to see that this is not a cash cow; indeed it cannot cover the costs. At Bolton, students are charged just £60 for registration with the OCNNWR and course materials, but joint accreditation with the OCNNWR gains the 'Access to HE' label which unlocks a further £575 per student (with a reduced rate for students who do not complete the course). With approximately 30 students per course, this roughly covers the costs incurred, but hardly any more.

These financial considerations may well be the answer to why the number of HEIs running Polymaths has declined over the years. Few universities would be willing to run a course which does not, at least, cover its own costs, and at this level of funding, even a small drop in student numbers in a single year would probably result in the course closing. We consider it a credit to both the maths departments and the respective university administrations that Bolton and LJMU have recognised the wider benefits of the course, in terms of widening participation and the contribution to mathematics generally, and continued to offer it.

There is, of course, the possibility that the fees to students could be raised. However, since this type of course appeals primarily to people considering a return to study after a break, we believe that keeping fees as low as possible is essential to reduce the barriers to a minimum.

Mature students in mathematics

Mathematics courses have a smaller proportion of mature students than many other disciplines. According to UCAS data [5], in 2007, 23% of UK applicants to university courses were aged 21 and older, and just over 20% of students accepted onto degree courses were this age. In comparison, in the subject areas of Mathematics (JACS subject line G1), Operational Research (G2) and Statistics (G3) (collectively termed MSOR here) only 4.9% of applicants were mature students, and 6.2% of accepted candidates were aged 21 or over. If we are to increase the number of mature students applying to study maths or related subjects then a variety of routes back into study are needed. We will write more about alternative routes for people interested in returning to study maths at a later date, but we note here only that part-time options are generally restricted to A-level courses (often daytime, at 6th form colleges with teenage classmates), Open University courses, and Polymaths. This – combined with frequent academic carping about the shortcomings of A-level – persuades us that Polymaths – in some form - is an option which should be actively encouraged.

Thoughts and possible options

It is clear that the questions of money and demand are key to any attempt to reintroduce Polymaths at other institutions. Assessing demand for courses is tricky when they don't already run, but if two universities in the North West both manage to maintain the course, it is probably reasonable to assume that – in it's present form - there would be sufficient demand for at least one or two courses in each of the government regions of the UK – say a dozen courses overall.

If we consider the financial implications however, we conclude that it would be very hard for a single maths department to persuade its university authorities to give the go-ahead. Under this model, the costs of running Polymaths would be borne by one department within one institution. However, the benefits are shared; financially any department within any institution which recruits extra degree students benefits, and more generally anything which increases the supply of mathematically competent people is something which we should welcome (as a simple example, increasing the supply of maths-specialist teachers benefits us all in the long run).

Having said that it might be difficult to introduce Polymaths in its current form at new institutions, we should note however that many institutions do run maths classes at a similar level, and often aiming to achieve a similar thing. There are modules within preparatory years and access courses at various institutions, which aim to provide access to undergraduate mathematics. There are support classes for engineering and science courses which cover roughly A-level equivalent.

Below we consider various options for what the IMA and university maths departments could do with Polymaths. Some of these are mutually exclusive, but not all, and at this stage only a couple are presented as recommendations – or in the case of the first option, something which we strongly discourage. We invite views on any or all of these options.

1. *The IMA could abandon its involvement in Polymaths.*
   We mention this only because not doing so would appear remiss, but we think this would be a mistake: doing so would be a disservice to the institutions which still run Polymaths since even if they continued to run the course, they would no longer be able to advertise it with the IMA brand. More importantly, this would be closing down one route into recruiting mature mathematicians. If there is a word for the opposite of a recommendation, we would attach it here.

2. *We could do nothing.*
   In other words, the IMA could continue to accredit the courses at Liverpool John Moores and Bolton in the same way as it does currently, but make no further effort to promote the course or the qualification. This seems to us to be a missed opportunity, whose only benefit would be that it was better than option 1 above.

3. *We suggest that a change in the name of the qualification be considered.*
   'Polymaths' is a pun which is 17 years past its sell by date; it's a word which is far too common to be effective in an age of googling for information; and it says very little about what the course does. We speculate that a Ronseal name may be better, for example 'IMA Certificate of Mathematics'. If OCN accreditation were achieved as at Bolton, then the tag 'Access to HE' could be included.

   We are not suggesting that this would necessarily be the title of the course, only the qualification. In the case of Bolton and LJMU it is likely that the Polymaths 'brand' is sufficiently well known that they would continue to offer a Polymaths course which, as now, could lead to a qualification of the IMA Certificate, or other qualifications for lower attainment. Other institutions could name the courses they offered according to their marketing department's whims. Indeed separating the name of the course from the name of the qualification offers additional options which are considered further below.

   One word of warning here: we all know the pitfalls of courses teaching to externally determined assessment regimes. Polymaths as it stands is not defined only by its assessment, but also by the style of teaching materials and overall course structure. Altering these, or separating assessment and teaching completely, would reduce Polymaths to just another qualification, and remove whatever advantages it has over A-levels.

4. Universities could offer the Polymaths qualification in conjunction with existing courses.
   If a university already runs a preparatory year, for example, it may wish to redesign the maths components of this to follow the Polymaths model. This would offer the advantage of pre-existing structure and teaching materials, for example. Most likely, the topics covered would be very similar to those already covered in preparatory years. The assessment used for Polymaths could double up as the assessment for the maths modules in the prep year.

   Students on prep years could be offered the IMA Certificate if they achieved the appropriate standard, alongside whatever qualification the university itself offered for successful completion. Where a prep year included Polymaths, admissions tutors would know how much maths was included, making prep years a more portable route to undergraduate maths.

   In addition, if timetabled suitably, the maths components of the prep year could be available as a stand-alone course leading to the IMA certificate.

5. *The IMA and the Heads of Departments of Mathematical Sciences (HoDoMS) together could decide to try to encourage the establishment of at least one Polymaths style course in each of the regions of England and Wales.*

   This may take the form of trials in, say, two of the regions initially, as a means to establish the likely level of demand, although we note that any such trial should be given sufficient time to establish itself.
   Ways in which HoDoMS/IMA might encourage this are, in effect, to adopt some of the options given here!

6. *New courses could be designed in such a way that the course can be accredited by the local Open College Network.*

   Although this creates an additional administrative burden, the increased funding available and the 'Access to HE' label probably outweigh the disadvantages.

7. *University authorities should be encouraged to view the course as part of their Widening Participation commitment,*

Many institutions now have separate funding arrangements for WP activities, and this could be used to persuade our ever-present accountants to put aside their usual financial models for assessing whether a course is viable.

8. *The number of courses in any region could be limited.*

   The IMA could decide that, in addition to its academic requirements for the course, accreditation will be withheld if there is thought to be sufficient existing provision in a region, in order to avoid competition rendering all the courses unviable. This option is only applicable if the qualification and the course remain inextricably linked.

9. *New courses should be run as collaborative ventures between universities.*

   Perhaps through HoDoMS or the existing regional consortia, or in collaboration with other numerate disciplines, courses could be run collaboratively between universities. Whilst the teaching would be based – initially at least – in a single institution, the finances (whether profitable or loss-leading) and marketing could be shared between institutions to reflect the shared benefits of running these courses. We are not so naïve as to underestimate the difficulties here, but believe that facing them can bring benefits to the whole discipline.

   Were this route to be followed, we would strongly discourage any action which harmed the existing Polymaths courses at Bolton or LJMU. However, if a model could be found to share the costs between institutions, it is possible that these two institutions may be able to benefit as the lead institutions in a local consortium.

10. *The IMA – in collaboration with institutions offering the course – should work to increase awareness of the qualification, both with potential students and university admissions tutors.*

    We could see benefits from an easier and more obvious link from the IMA's website homepage, to a page with details of the Polymaths course, with the syllabus and structure available so that admissions tutors can see what the course offers. If new courses are established, direct contact with admissions tutors in various numerate disciplines to explain Polymaths should be considered.

11. *A distance-learning version of Polymaths could be developed.*

    One obvious possibility for developing Polymaths, given relatively small numbers of geographically spread potential students, would be to develop a distance learning version of Polymaths, perhaps using new technology such as Elluminate. The Further Maths Network has experience of this [6] for A-level study. Clearly this deserves consideration, but we offer a word or two of caution: mature students returning to study for the first time are often less confident in the use of technology; indeed they are often less confident generally and appreciate the face-to-face contact even more than younger students; and students who are willing to take a distance learning course can already access Open University courses which would serve a similar purpose [7]. In addition, developing a distance-learning version of Polymaths would require time and money beyond that which is required to establish courses using the existing Polymaths material.

Conclusion

The barriers to establishing new Polymaths courses are substantial: unknown demand, but probably low student numbers; the need to keep fees to students low; the costs being borne by one institution rather than shared by all the possible beneficiaries. However, the possible advantages include increasing the supply of students capable of studying mathematics, whether on maths degrees or in other numerate disciplines, and the knock on beneficial effects for the maths 'ecosystem'. In addition, this is a long-running programme, with well-regarded existing course materials (and associated low start-up costs), which offers a part-time route back into study, which is rare.

In this article, we have considered various options by which Polymaths could be revived across the country; we now invite any comments and alternative suggestions, in the hope of further discussion and development within the maths community and the IMA in particular.

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If you have comment to make, please send them to Mike Robinson at m.robinson@shu.ac.uk

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2.4 *Accessibility of Mathematics Degrees to Adult Returners*

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Introduction

A significant minority of potential undergraduate mathematics students do not, for a variety of reasons, enter into a degree course immediately after leaving school. Those wishing to return to study later can do this through the Open University, an Access to HE Diploma at a college, a University year zero (normally referred to as a Preparatory Year or a Foundation Year, not to be confused with a Foundation Degree) or sometimes by part-time A-level study at a college. The Institute of Mathematics and its Applications (IMA) validated "Polymaths" course is also still thriving at a couple of institutions, in one case linked to an Access to HE Diploma.

Students coming into these courses fall into two broad categories. The first consists of "near school leavers", students who are only a year or two older than school leavers, and who have not yet really started a career. By contrast, in the second category are students who have been away from education for a number of years, in employment, raising a family or a combination of the two. It is the latter group of "returners" that is the main focus of this article.

In particular we look at some of the educational and financial pros and cons of particular routes and at factors influencing course choice and possible reasons why (as noted in an earlier article [1]) mature students are under-represented in mathematics compared to the average across subjects. One factor which emerges is the lack of standardisation between courses and the implications of this for university entrance and the level of preparedness for starting a university degree. It is also apparent that returners often only have partial information about courses and careers.

In researching this article, we drew on a number of sources. We interviewed, in person or by phone, staff and students from 8 colleges and universities in 4 different regions [2]. We also had email contact with a further 3 institutions [3] and looked at a number of government and other websites. This evidence base, whilst not providing comprehensive national coverage, does provide a reasonably representative cross section.

Reasons for Returning

The two most common reasons given for adults returning are, probably as would be expected, boredom or lack of progression opportunity in current employment, and a wish to get back into full-time employment after raising a family. One student described how they had worked in retail for 20 years and had reached a position where there were no further opportunities for promotion. Another said that they were bored with their job but did not have the qualifications to go elsewhere. This student also commented that their children were growing up, and hence did not require so much attention, but an additional reason for study was to help them with their homework. A third student in their mid forties with three small children had been inspired to study for teaching after helping out at their children's school and talking to the head teacher. These are typical of the UK students that we spoke to, but there is also a significant number of students from other parts of the EU who have settled in the UK and either do not have previous qualifications, or have qualifications which are not recognised here. An example of this was a student with a degree in the finance area from another EU country which was not a useful qualification in the UK because of differences in finance law.

Course Choice

Students who want to return to study primarily because of an interest in mathematics have the option of studying on specialist mathematics courses. These include the Open University, some university year zeroes, some specialised access courses, and Polymaths.

Returners motivated by a desire to upgrade qualifications for employment where they live are more likely to seek a course which they recognise as being vocational. Careers such as teaching, social work, nursing and other professions allied to medicine are well-known and respected and potentially available in most places, and hence are often the starting point for study. By contrast, students seem much less aware of the sort of employment opportunities offered by degrees, like mathematics, that don't appear to be directly vocational. No-one spoke for example of having consulted the Maths Careers website [4]. A colleague in an access course team commented that their students could not see possible employment prospects for mathematics graduates in their locality and indeed the publicity for access courses both at college level and on the Access to HE Diploma website [5] emphasises access to recognised vocational degrees. The problem is exacerbated in some areas of the country, identified in the Steele report [6] as "mathematical deserts". In such areas the lack of local degree level maths provision is likely to act as an additional deterrent against returners choosing mathematics.

Despite these disincentives however, once on a returners' course and having been exposed to mathematics, a small number of students decide to change track and aim for a mathematics degree. Two students described how they had come on access courses, one aiming for social work and the other for PE teaching, but had become interested in maths through their course and were now considering applying for entry into a maths degree. A student now on a maths degree described how they had studied on a university year zero angled towards biosciences, but containing a small proportion of maths, and had decided to change to maths rather than continue with their original aim towards the health professions.

Information about the Open University is widely known, but students studying either full-time or part-time "face to face" spoke generally of the difficulty of getting information about courses. Two students now on a maths degree knew of Access to HE Diploma courses only through friends or relatives. One commented that it was difficult to find out about a particular year zero even when they knew it existed. Other students noted that the access course that they were studying on was the only course that they knew about. To some extent this is surprising because the UCAS site [7] currently includes a page on access programmes and a link to the Access to HE site [5] which gives comprehensive information on Access to HE diplomas. There is no equivalent site however for university year zeroes and the difficulty of tracking them down is compounded by the fact that UCAS course codes (eg G101) may be used for a year zero at one university and something different at another university. It seems then as though the difficulty students experience in finding information is in some cases because they are not sure where to look and in others because the information is not available. In either case this difficulty, together with lack of knowledge about associated careers, may be a contributing factor to the under representation of mature students in mathematics.

Of students we spoke to who had considered various options, one had opted for a university year zero because they thought that, for university admission, there would be an advantage in already being in the university system. The same student felt that they lacked the discipline to study without being constantly surrounded by a peer group and readily available face to face support, despite having a relative who had successfully completed an OU course. Another student in their late 20s on a maths focussed access course had completed GCSEs at a local college, but had found it difficult being surrounded by 17 year olds and had found their current course by an internet search. This student also mentioned that they wanted the experience of going to university rather than study by distance learning.

Several students said that they had considered studying for A-levels but had opted for an access course because it was shorter and/or because there was no locally available A-level course.

Content and level

The amount of mathematics in returners' courses varies substantially. Open University and Polymaths courses can be almost entirely 100% mathematics, and some university year zeroes and maths focussed access courses are at least 50% maths, so that students may spend 6 - 8 hours a week on mathematics. At the other end of the spectrum, on some access courses with fairly low numbers studying mathematics, it is only viable to teach 3 hours of mathematics and statistics per week.

The Open University is not only the largest single provider of pathways into mathematics for adult returners, but also considerably larger than all other providers put together. A rough comparison can be obtained by looking at the number of students of age 25 and over studying first level 2 Open University course MS 221[8] against the total number of UCAS acceptances [9] for maths (JACS codes G0 and G1) in the current year for the same age range. This gives a figure of 1550 compared to 153, a factor of about 10. Courses provided by the Open University at the "year zero" level give varied entry points depending on previous experience, from no previous mathematical experience (Y162) through basic confidence with arithmetic (MU 120), to good top level GCSE (MST121). These courses lead naturally on to the level 2 courses provided by the OU and, in a small number of cases, students use Open University accumulated credit to gain acceptance at either first or second year level on full-time degree courses at other institutions. Courses are part-time and distance learning and thus provide a great deal of flexibility in study pattern to fit around child care and full-time employment.

Access to HE Diplomas are validated by the Open College Network (OCN) and are available in full time and part time mode (although not necessarily both at the same institution). With a couple of exceptions the curriculum is fairly broad and mathematics is one subject among several, occupying typically 20% of the curriculum. The timetable is designed with returners in mind and is usually "school friendly" for students with school-age children. The OCN have a bank of module descriptors which colleges must choose from. There is a formal validation process for allowing colleges to run particular modules and colleges do not have a completely free hand about which they choose.

A colleague at one college described how their original choice of modules had been rejected by OCN after a lengthy validation process, and the final validated set of modules had some overlaps and some gaps. A colleague at another college spoke of submitting additional modules for validation in the middle of a year to maximise compatibility with A level, and felt the best strategy was to validate more than the minimum to provide greater flexibility about what is taught. There was a consensus view that experience of teaching A level was desirable in order to be able to interpret the level of the Access to HE module descriptors appropriately and to choose the appropriate diet of maths modules. Typically an access course includes modules which cover the majority of the range of calculus techniques covered in A level, but not all in as much depth. Different access courses then cover different additional areas, often including some statistics. A maths-focussed access course also covered discrete mathematics.

To pass an Access to HE Diploma 60 credits are required, of which at least 45 must be at level 3, and the remainder at level 2 or above. Universities often make offers insisting on a greater number of credits at level 3. One colleague expressed the view that students without a prior GCSE or equivalent background would find it difficult to embark on level 3 maths studies. There are exceptions though, we met one mature student who started on level 2 without prior GCSE maths at the beginning of the year, swapped to level 3 after Christmas and was now successfully completing the full level 3 diet within the year. Access courses are assessed using a criterion reference system. Each module descriptor specifies a range of tasks at which students have to show competence. Once this competence is demonstrated then all the credits for that module are gained. There is no percentage score associated with a module, and there is no partial credit awarded. Percentages can informally be given, but these are not accepted by OCN as relevant to the assessment of the diploma. It would be possible to gain 75% and not pass the module because criterion referencing demands evidence of ability in all aspects of the module.

This is rather a different system from A-levels, although a colleague with long experience in teaching both A-level and Access courses was clear that in some ways the criterion referencing was more stringent than A-level assessment and was a good test of the students' ability with the material taught to them. The point was made that this stringency was not always appreciated by universities and this, together with the varying mathematical content of access courses, could make the University admissions process more difficult. Colleagues recounted how they had had to send access course validation documents to admissions tutors to verify the level of mathematics studied and of cases where, despite the criterion reference assessment, universities had framed offers in terms of percentages, one requiring an average of 90%. Universities also frequently ask for more credits at level 3 than the stipulated 45 needed for the Access to HE Diploma, and we were told of one instance of a university asking for more credits at level 3 than the total number of credits on the course. In another case a native Polish speaker was asked for IELTS level 9 (compared for instance with a typical IELTS 6.5 required in the UK for postgraduate study) in addition to the Access Diploma. Anecdotally we were told of one university admissions tutor who was not short of applications from good A-level candidates and considered applications from Access students reluctantly, and some of the above offers perhaps emphasise this reluctance. To put this in perspective however, an experienced admissions tutor, well conversant with Access courses, expressed severe reservations about the feasibility of proceeding from some of them on to the degree course for which he was responsible. His experience with some past students was that it was extremely difficult for them to survive in a highly specialised mathematical environment given their limited amount of prior mathematical practice.

University year zeroes fall into two categories, those with a fairly general curriculum, aimed towards science and/or engineering, and those which are more specifically targeted towards mathematics. Although courses are normally designed for full-time study, part-time study is often possible. This may however involve picking modules from a full time route, giving a rather unfriendly timetable. For the more general courses, typically about 25% of the course is mathematics, while for those more specifically targeted towards mathematics, the mathematical content comprises typically between one third and one half of the course. Usually the core of the maths studied is algebra, trigonometry and calculus, with substantial variation in the amount of integration covered. Additional topics in some year zeroes are typically drawn from statistics, computational maths, logic and discrete maths.

There is no overall body regulating year zeroes as there is for access courses and hence assessment schemes vary widely, with a mixture of coursework, frequent small tests and more formal examinations. On passing the year zero some universities give automatic access to maths degrees, while others set criteria above a bare pass level for entry into degrees, and may require different levels for different degrees (eg for MMath or for degrees such as actuarial science that are perceived to be particularly demanding). One function of these courses is to help students of normal school leaving age who either have the wrong A-level profile for their chosen course or have not performed sufficiently well in their A-levels. Some courses assume mathematical study beyond GCSE, while others start essentially with a revision of GCSE material. Entry qualifications are negotiable for adult returners depending on life experience, but clearly it may not be realistic for an adult with no recent experience of mathematics to aim for a course which assumes some A-level study.

For an adult returner with a firm intention to study mathematics at a particular university, a year zero is straight-forward as often no additional application procedure is required to proceed to the degree. It is also often possible to proceed on to a related degree such as engineering from maths-focussed year zeroes, or for students to continue their studies after the year zero at a different university. In both these cases however entry would normally be by application rather than automatic, and transfer to a different university is likely to require the same sort of verification of course content as reported above for Access to HE Diplomas. Embarking on a year zero may not give as much choice on future directions as an access course, although the amount of maths covered is likely to be greater and, in the case of year zeroes associated with particular degrees, may lead more easily on to the first year of the degree course.

Polymaths is a part-time one year roughly A-level equivalent course starting from approximately GCSE level, originally set up by polytechnics in the 1970s under the auspices of the IMA. For a fuller description and discussion of the qualification see [1]. Although now only run by two institutions (Liverpool John Moores University and the University of Bolton), in these institutions it works well. At Bolton, the course leads to the award of an Access to HE Diploma in addition to the IMA Polymaths certificate. Assessment is continuous and through frequent objective tests and longer periodic tests completed by students at home. Both institutions run the course over two evenings per week. Very well known at one time, at least within the ex- polytechnic sector, the course is now not always as well known, necessitating the provision of additional information to admissions tutors in a similar way to access courses and university year zeroes. Offers to maths degrees from Polymaths are given either on the basis of a pass (700 out of a total of 1200 marks) or possibly with the specification of a higher mark for particular courses.

Evening A level courses in mathematics are now few and far between, but where they exist provide another option for returners to bring their maths up to university entrance level. It is also possible to take A levels full-time at a college, but these courses are primarily geared to students who have just taken GCSE and have the disadvantage compared to an Access to HE Diploma or university year zero that study is over two years.

Finance

The cost of fees and level of support available vary not only between different routes and different individual circumstances, but also, in the case of Access to HE Diplomas, between different colleges offering the same course. For the Open University, depending on individual circumstances, a fee grant is available to pay for course fees and to make a contribution towards study costs [10]. Currently at a joint household income of £31000 for instance a grant of £200 is payable towards fees. If the income is £21000 then £547 would be available towards fees with an additional £260 towards study expenses. Fees, depending on courses studied, are in the region of £700 for 60 credit points. These can be paid in instalments with an OU student budget account. Students can also apply for access to learning funds for help with study related costs such as child care, travel costs etc.

Access to HE Diplomas are normally financially supported by the Learning and Skills Council (LSC). Full fees on access courses can be up to about £1300 per year but vary significantly between colleges. Many students pay a much reduced fee, including those who are on income support and other benefits and have not been educated beyond level 2. Exact categories again vary between colleges.
In addition to reduced fees, there are a number of other sources of help, e.g.

- Adult Learning grant [11]
  This is up to £30 per week depending on household income and the student must be studying their first full level 2 or first full level 3 qualification at a learning provider funded by the LSC.
- Discretionary support funds [12]
  For students who are 16 or over and are studying an LSC funded course. Colleges determine priority groups and amounts, so these vary from college to college. Typical priority groups are those who are economically disadvantaged, those over 19 without a level 2 qualification and those who have been in care or on probation.
- 20+ Childcare [13]
  To receive this students must be over 20 and studying full or part-time in an FE college on an LSC funded course. Amounts vary between institutions and cannot be used with the Free Childcare for Training and Learning for Work Scheme.
- Free Childcare for Training and Learning for Work Scheme [14]
  For this scheme students must be over 20, and not working but with a partner who is working and with a household income of £20000 per year or less. Amounts are currently up to £175 per week outside London

The diverse sources of help make it difficult for students to know in advance exactly how much help they will be able to get. One student had, after some debate, received a lot of help with travelling expenses from their college through discretionary support funds and this had gone a long way towards making their study possible. Another student pointed out that some funds depend on household income, including a partner's income, irrespective of the longevity or stability of the partnership. This student felt that while there were potentially a lot of sources of help, they had just missed out on a number of them. There was a feeling that study was financially possible if you had sufficient funds to pay for it, or if you had little income, but that there was a band of students in between who had just enough income to not qualify for extra support, but not really enough to pursue their chosen course.

When studied full time, the funding for university year zeroes works in the same way as subsequent years of a university course with a student loan. If they have not studied in HE before, students are potentially eligible (depending on other sources of income) for both a tuition fee loan and a maintenance loan [15]. If the household income is below £25000 then students are eligible for a full maintenance grant which pays the majority of the fees. This reduces on a sliding scale up to about £50000. Outside London the maintenance loan is currently up to £3564. Fees vary a little between institutions and we were told of at least one case where fees for the year zero are lower than for subsequent years of the course. Students in difficult circumstances can receive additional funding from the Access to Learning Fund [16]. This comes from a fund paid directly to universities who then decide on eligibility and amount paid. Students studying part time can also be eligible for help via a course grant and fee grant depending on household income, receipt of benefits and intensity of part-time study. One student spoke of difficulties in obtaining funding for part-time study when a university were willing for him to study part-time on a full-time course, but the course was not officially validated in part-time mode.

The surviving polymaths courses both charge very low fees [1], one at around £200 per year (priced as a positive contribution to the institution's widening participation commitment) and the other at approx £60 per year, this latter course being supported by the LSC since it also leads to the Access to HE Diploma.

As is clear from the references quoted in this section, there is comprehensive information about finance on the web. There seemed to be a general feeling among students however that sources of finance are complex and difficult to find out about. This may be because the information is in a number of different places and there is the problem that you don't know what to search for if you don't know that it exists.

Support, Performance and transition to first year studies

Whichever option adult returners choose, they are normally following a course which is half the length of a traditional sixth form A-level preparation. Combine this with the length of time which many students have been away from study, and it is clear that returners display a very high level of commitment and require considerable support. As one access tutor pointed out, the students come from a variety of backgrounds, most have to work unsociable hours and often come to college straight from work, or go to work straight from college.

The high level of Open University support for students is well known, and students also spoke almost unanimously of the excellent support given to them in Access to HE and Polymaths courses. This was backed up by the self evident care with which college staff spoke about their access students. Sometimes in university year zeroes, students are in much larger classes and this does not always allow for the same level of personal support. One former year zero student spoke of the difficulty in a large lecture of asking questions about aspects of integration because no-one wanted to be the first to ask in front of a large number of people.
On university year zeroes, adult returners tend to be in a fairly small minority (typically 0% to 25%) compared with those basically changing track after A-levels, or enhancing their preparation for their chosen degree in the year or two after leaving school.

Of students who start Open University "year zero" level mathematics courses approximately 30% move on to study higher level maths courses [8], the remainder either use these courses as a route to studying science, engineering or computing or do not study any further. In the access courses we visited, most students were successful although only a small number were proceeding on to mathematics degrees. Anecdotally there is a significant proportion (between 25% and 50%) of all those starting university year zeroes (adult returners **and** near school leavers) who, for a variety of reasons, do not progress through on to the first year of the degree at the same institution. There is some evidence to suggest that the number of students withdrawing for reasons unconnected with their course is disproportionately high. This may be because students entering a year zero, both returners and near school leavers, are often not completely sure of their direction. There is a proportion who, after some time, feel that they have chosen the wrong course. Others find that they cannot cope with the demands of study and there are also some who change institution and study elsewhere.

Students coming on to maths degrees from a year zero or an access course often do not find the going easy. One student, now in their second year, spoke with wry humour of joining a mathematics degree from a year zero containing only a small proportion of mathematics and "hanging on by my fingernails" ever since. This student spoke of the steep learning curve, and the fact that they had to look everything up rather than having standard results at their fingertips and so everything took much longer. Another student who had followed an access course with a maths focussed year zero still felt that their basic core knowledge was not as good as the students from an A level background, and that the pace of the year zero was such that they were "playing catch up" the whole time with no breathing space. They made the point however that if a year zero were spread over two years it would not attract students. Another student from a different (non maths-focussed) access course had also found things difficult on the degree and said that they thought that the amount of mathematics they had studied on the access course was not really sufficient.

Some of the feelings expressed possibly come from a lack of confidence since adult returners who make it on to a maths degree course often do very well. In one institution students from a year zero performed only marginally less well on average than students coming from A-levels, while at another institution year zero students generally performed slightly better than students from A-level. In a third, although year zero students generally performed rather less well than A-level students, the adult returners amongst them performed significantly better.

Summary

For a large number of students, the Open University is an excellent option because of the flexibility of study around a full time job, and also the flexibility of starting point in the study programme. For a substantial minority however the advantages of face to face support, length of the course and the "going to university" experience make other options preferable.

Access courses are, with a couple of exceptions, fairly general in their curricula giving the advantage (within the constraints of the UCAS application procedure) of delayed choice. A disadvantage is that the time given to mathematics is less, which makes the transition to the first year of a maths degree course a more difficult one and this may well contribute to the small number of students opting for maths degree courses. Class sizes tend not to be large, students are very well supported and are likely to find a significant number of other adult returners in the class. For students whose personal circumstances and/or previous study qualify them for funding then study is financially possible without accruing large debts.

University year zeroes can be fairly general, allowing some delayed choice although there will typically be a little more maths than in an access course. Some year zeroes are more directly focussed towards mathematics, and are a good option for students who know from the outset that they want to do mathematics. An advantage of university year zeroes is that they are often formally part of a degree programme, so that passing the year zero gives automatic entry to year 1 of a degree without any further application process. Conversely classes can be much larger than on an access course, with the majority of students being near school leavers. For full-time study student loans and grants are available on the same basis as for school leavers. Both access courses and university year zeroes can be studied on a part-time as well as a full-time basis but, at least in the case of year zeroes, not always with a user-friendly timetable. The part-time routes include the two remaining Polymaths courses which both run on two evenings per week. Although part-time students aren't eligible for student loans, LSC related funding for access courses and course and fee grants for year zeroes are available depending on personal circumstances.

Potential returners generally find it difficult to obtain information on the pros and cons of various courses, on possible career options in mathematics and on ways of financing their studies. Currently the Maths Careers website [4] provides detailed information about careers and some information and links about courses, the UCAS site [7] includes a page on access programmes and a link to the Access to HE site [5] which summarises access provision. The Open University site [17] gives excellent information on Open University courses. Conversely centralised information seems to be lacking on University year zeroes, and there seems to be no single place which gives an overview of the pros and cons of taking various different returners' routes. Also, while there is comprehensive information on finance on the web, it is in a lot of different places and is difficult to navigate through for a returner unfamiliar with HE.
Even where there is good information available, it seems from our discussions with returners, that awareness needs raising about where to find it.

Several colleagues and students spoke about the difficulties in applying to mathematics degrees from returners' courses. Anecdotally there is a lack of knowledge about these courses amongst some university admissions tutors, and possibly a reluctance to take students who have not followed a traditional A-level route when there is a plentiful supply of those. This may be partly unfamiliarity with the qualifications and different methods of assessment, but the difficulty is compounded by the widely differing amounts of mathematics in returners' courses. Deep concern has been expressed, for example, by admissions tutors with experience of access courses about the limited space given to mathematics in some of them. While the level of study in a returners' route is verified by OCN or University validation procedures, with the exception of Polymaths validated by the IMA, the amount of mathematics included in the route is not. Because the qualifications are less well known, and have widely varying mathematical content, students applying from returners' courses and staff supporting them often have to supply detailed information about course content to admissions tutors. Offers given on the basis of this don't always align well with the course structure or methods of assessment.

Although we were only able to speak to a small number of students on maths degrees that had come from returners' courses, the consensus amongst them was that they felt less well prepared than students who had come straight from school. In particular they did not have techniques at their fingertips in the same way as some of their younger classmates. This may be partly because they have not had the several years of continuous mathematical study enjoyed by school leavers, and also partly a matter of confidence. Nevertheless there is a message there that there needs to be substantial opportunity for mathematical practice in returners' courses, more than there is in some at the moment.

Recommendations

Currently the number of students coming through returners' routes on to mathematics degrees is small. Despite their misgivings about comparative standards with school leavers however they can perform very well. It seems likely that not all students who could profitably take a mathematical route are doing so, partly because of lack of information and partly because of a slightly awkward interface between returners' routes and degree courses. While numbers may never be huge, from the points of view of fair access for all, and enriching the community of learning in our degree courses, it is important that the difficulties identified are addressed. Some may be tackled directly and others require further investigation, possibly as part of the STEM project about to commence [18]. We make the following recommendations:

1. Information on the pros and cons of different returners' routes

The Maths at University Guide (in booklet form) currently being prepared by MoreMathsGrads in association with the London Mathematical Society (LMS) will give detailed information about the spectrum of maths degree courses and possible outcomes. It would be useful if this were supplemented by a booklet giving information on the pros and cons of different paths into a mathematics degree for adult returners. The same information should be made available on the web, perhaps as an addition to the Adult Learners section of the maths careers site [4].

2. Single search point for university year zeroes

To make all possible options easy to find, a site giving a single search point is needed for university year zeroes equivalent to the Access to HE site [5] for Access courses. This could be closely linked to the Access to HE site, or perhaps even part of a combined "Adult Returners" site.

3. Guide to finance

Although there is comprehensive information on the web about finance, the rules are complex, and the information is distributed among a number of different sites [10-16]. Anecdotally students find it difficult to estimate the amount of financial support they can obtain in their particular circumstances, and don't always know about the full range of grants, allowances, benefits and other funds available to them. A single guide through the financial labyrinth would aid potential returners significantly in considering all their options. This could be as a separate booklet, or as an additional section to the booklet on courses suggested in recommendation 1 above, and should also be repeated on the web.

4. Study to establish information gathering strategies

Even where good information exists, it often does not find its way to all the people who would find it useful. Potential returners are likely to have contact with job centres, and often look at publicity for local colleges. Further work is needed however to establish the full range of information gathering strategies that they adopt and the nature of the information that they come across by using these strategies. Would they be directed to the maths careers website [4] for example by a college or job centre? Such a study would enable steps to be taken to ensure that not only does information exist, but that it is available in places where potential returners are most likely to find it.

5. Kite Mark for Mathematics content

It may be helpful if there were a recognised "core entry mathematics" included in returners' routes which was widely understood to be a suitable preparation for entry into a mathematics degree. In terms of content, and time allocated to it this "core entry mathematics" would be broadly equivalent to an A level course and for some returners' courses would represent an increase in the current mathematical content. Such a standard core would address both the problem of recognition of returners' qualifications and concerns expressed about the level of mathematics contained in them. The content would need to be verified in some way, and a possible mechanism could perhaps be an evolution of that currently used by the IMA for Polymaths.

Acknowledgement

We would like to acknowledge the generous help of colleagues, and in many cases also students, at the institutions listed in [2] and [3] below who gave freely of their time and, where we visited, made us very welcome.

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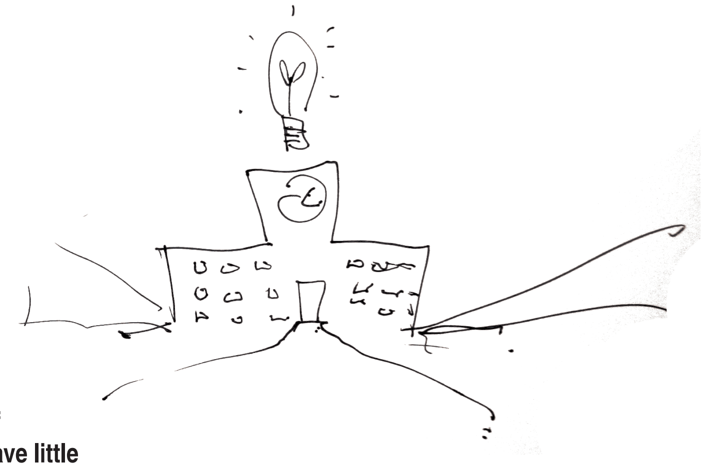
2.5

Maths at university – a guide for potential students



One of the findings that emerges from our conversations with staff and students is that before arriving at university, many students have little idea of what to expect – or mistaken ideas.

Mathematics courses are not all the same. This is a truth well known to professionals, and explicitly supported by the MSOR Subject Benchmark Statement [1], but perhaps less well known by potential students. It is also possible that widespread knowledge of a national curriculum at school leads some to believe that universities also have a common curriculum.

Courses and their parent mathematics departments vary in many different ways. These include curriculum content, the approaches taken to the material (to use the benchmark terminology, 'practice-based' or 'theory-based'), the size of the department, the amount of contact time, the extent of research conducted in the department, the attitudes to the use of technology, the availability of years abroad or in industry, the support offered to students, and the destinations of graduates, amongst others.

Despite this, there is evidence that the differences in the courses are rarely a driving factor in students decision-making; only 1 in 20 cite aspects of the course as having been the most important factor to them [2], whereas the reputation of a department and external factors such as the city feature much more.

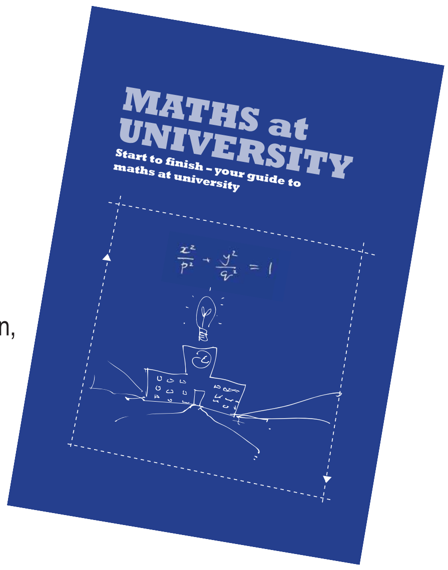
This is regrettable. The wide variation in courses means that some students would be happier and more successful at one university rather than another. This is no reflection on the quality of the provision at either; simply a statement of the idea that it would be preferable for us to get the right student onto the right course. This is also in our interests; happy successful students generally result in contented staff as well.

To this end, we have written a booklet Maths at University aimed at potential mathematics students. Its aim is to help them to make an informed decision about their options for study.

The guide does not attempt to describe individual courses or to say what type of course is best – far from it. We believe wholeheartedly that the diversity of courses is of huge benefit to students and to the mathematical ecosystem overall.

The guide has four main parts:

- a series of questions and answers about applying for and studying maths;
- profiles of a handful of students on mathematics courses;
- suggestions for research/questions that potential students should pose about courses they are considering;
- a brief description of some of the subjects that students are likely to meet during their first year studies.



The guide is jointly published by the MMG project and the London Mathematical Society. In preparation, draft copies were widely circulated for comment, and although it is inevitable that some staff may take issue with some parts of it, we hope that overall it will gain widespread acceptance by universities and be promoted by admissions tutors as well as widely used in schools and sixth form colleges.

The booklet will be circulated to schools and universities during January 2010. To order further copies, please visit the Maths Careers website [3].

Mike Robinson, Mike Thomlinson and Neil Challis

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3.0 Student and staff experience

3.1 *From the horse's mouth 1: Student confidence and enjoyment during undergraduate mathematics*

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1 Introduction

In this article we discuss what students told us about their confidence and enjoyment in mathematics during their undergraduate course.

We do this in the belief that this should be of interest to the Higher Education (HE) maths profession for two main reasons:

I. E**ducational**: Students' enjoyment and confidence is intimately linked with both their understanding and motivation during their course, and hence their performance. This is hardly surprising - happy confident students work hard, enjoy their studies and learn more, and hard-working students who learn well tend to become confident and happy. Some of the quotations from students included in this article reinforce the idea of this virtuous circle involving enjoyment, confidence, understanding, motivation and performance.

II. R**ecruitment**: Given the eponymous aim of the More Maths Grads (MMG) project, at the heart of the HE Curriculum theme of the project lies a key question: "What happens in university mathematics that might encourage or discourage future students from opting for the subject?"

Actually, the latter question begs another, which we should deal with briefly here: namely whether what we do in university is actually likely to have much impact on prospective students; after all, perceptions of university courses are influenced by many things, from current schoolteachers' memories of their university days through to popular culture's apparent belief that mathematicians are strange geeky geniuses with poor interpersonal skills and worse personal hygiene. Whilst it will probably always be true that our image to outsiders will be a caricature, we take the optimistic view that with ongoing outreach work – influenced by, amongst others, the other parts of the MMG project –the perception will in the end become more of a reflection, albeit no doubt distorted, of the reality. It is therefore essential that we make sure the reality stands up to scrutiny. Reality here might be the specifics (do we assess/teach/support well?) but are as likely to be the more subjective overall satisfaction of students (do they leave with happy memories of their time doing maths?). For this reason we believe what students say about the enjoyment and confidence is particularly important.

Furthermore, what they say covers the whole gamut of HE experience. As such, this paper and its sister paper [1] (on the improvements students wish to see) serve as an introduction and overview to the issues of concern to students, and hence (we hope) of concern to HE staff, whether we are concerned with the experience of our current students; what they might say about us in, say, the National Student Survey (NSS) [2]; or in increasing the number of students applying to study maths.

In other articles throughout this publication we have discussed further these specific aspects of undergraduate mathematics provision, drawing on interviews with staff and first year students at four institutions.

2 Methodology

The results in this paper draw on an online questionnaire which was open to students in any year, studying single or combined honours mathematics at four institutions. The survey was advertised to these students via email sent by the course staff, and through posters displayed in the departments. A number of prizes were offered, to be awarded randomly from those students who completed the survey, to encourage students to participate, but students could also opt out of the draw in order to remain anonymous.

The survey included a variety of closed and open-ended questions. We asked initially about the students' prior learning of mathematics, and their current level of study and course. We asked them to rate their confidence in mathematics before arriving at university, and to say whether this had increased or decreased during their first year of study. For those who said their confidence level had changed, we then asked them in an open-ended question to give the biggest reason for this, with some prompting about the possible answer they might give, as shown in Figure 1. We repeated this format, this time asking them about their enjoyment of mathematics.

For students beyond their first year of study, we also asked them to compare their confidence and enjoyment levels now, compared with during their first year. Again, if this had changed, we asked them in an open-ended question to give the biggest reason for this.

It is the results of these questions about confidence and enjoyment that we report in this paper. Other questions raised in the same questionnaire, for example about the best and worst aspects of the course, what students wish to see improved, and whether they would choose the same course again are reported elsewhere [1, 3]

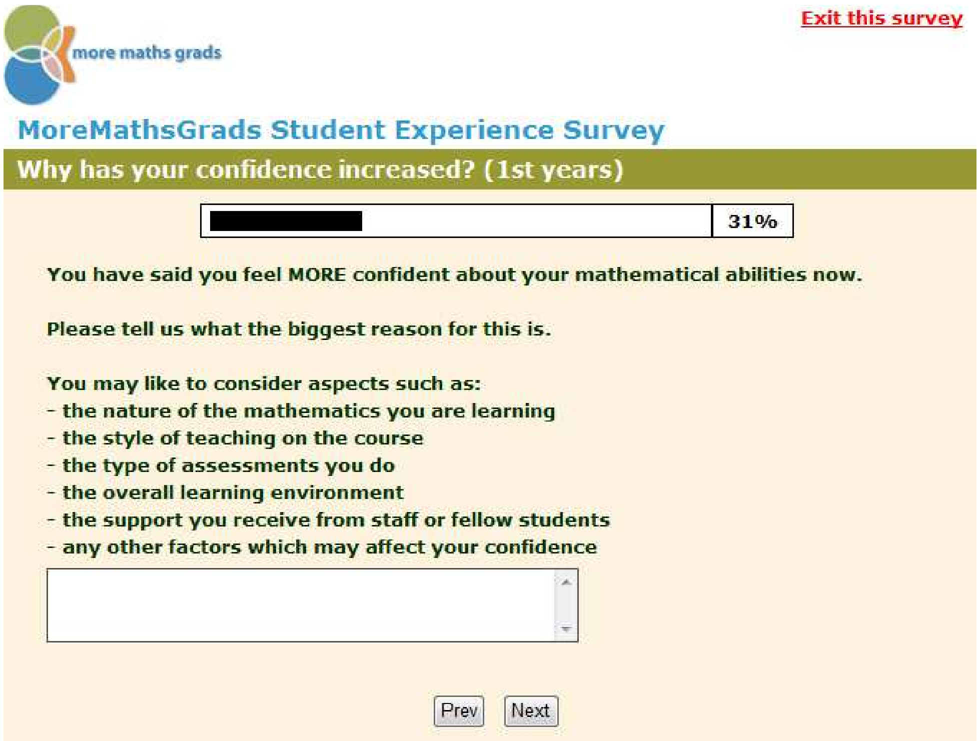

Figure 1: Example question asking students to explain why their confidence level changed when at university.

In all 126 students started the survey; 105 completed it, and of these 16 opted out of the prize draw to maintain their anonymity.

2.1 Limitations and advantages of this approach

An obvious problem with this approach is that we cannot guarantee that the sample of students surveyed is representative; we therefore view the statistical results presented in this article with a healthy degree of scepticism which the reader may well share. Nevertheless we present the quantitative data for information.

We are more interested in the response to the open-ended questions, where the number of responses overall gives us a wide range of opinions on what is good, or bad, about the experience of studying undergraduate mathematics. Crucially, this approach means that the results constitute a review of the state of our mathematics courses from a student perspective rather than from a staff perspective; in other words the issues raised are the ones which our students report, rather than those which we choose to raise.

3 Quantitative results

3.1 Confidence and enjoyment during the first year of university study

Table 1 shows the number and proportion of students who said that, during their first year at university, they felt more or less confident, and enjoyed their maths more or less than they had before university. A number of points are worth noting:

- As we might expect, there is a strong correlation between confidence and enjoyment. However, there are a few students (9, 7.6%) who found one had increased whilst the other had decreased, and we shall consider the reasons for this later.
- Encouragingly, 39.8% felt more confident compared with their pre-university experience, but conversely 28.8% felt less confident.
- Similarly for enjoyment: 32.2% enjoyed maths more against 22% who enjoyed it less.
- Exactly half the students reported that one or both of their enjoyment or confidence levels had improved since started university, whereas 40% reported that one or both had decreased compared with their pre-university experience.

		Enjoyment					
		Lot less	Little less	Same	Little more	Lot more	**Total**
Confidence	Lot less	5 (4.2%)	3 (2.5%)	3 (2.5%)	-	-	**11 (9.3%)**
	Little less	1 (0.8%)	5 (4.2%)	12 (10.2%)	-	5 (4.2%)	**23 (19.5%)**
	Same	1 (0.8%)	7 (5.9%)	22 (18.6%)	7 (5.9%)	-	**37 (31.4%)**
	Little more	-	4 (3.4%)	12 (10.2%)	8 (6.8%)	4 (3.4%)	**28 (23.7%)**
	Lot more	-	-	5 (4.2%)	6 (5.1%)	8 (6.8%)	**19 (16.1%)**
	Total	**7 (5.9%)**	**19 (16.1%)**	**54 (45.8%)**	**21 (17.8%)**	**17 (14.4%)**	**118 (100%)**

Table 1:
Number of students who said their confidence in and enjoyment of mathematics during their first year had increased or decreased compared with their pre-university experience.

3.2 Confidence and enjoyment during later years of university study

Table 2 shows the equivalent data for how non-first year students rated their confidence and enjoyment now compared with their first year experience. This appears to be a more encouraging picture than during the first year:

- Again there is a strong correlation between confidence and enjoyment.
- Encouragingly, 63.9% felt more confident compared with their first year of study, compared with 19.7% who felt less confident.
- Similarly for enjoyment: 50.8% enjoyed maths more against just 8.2% who enjoyed it less.
- Over two-thirds of students (68.9%) reported that one or both of their confidence or enjoyment had increased since their first year, whereas 19.7%% reported that one or both had decreased.
- Of all the combinations of confidence and enjoyment ratings, the highest proportion (26.2%) is those students who say that both confidence and enjoyment have increased a lot.

		Enjoyment					
		Lot less	Little less	Lot less	Little less	Lot less	Little less
Confidence	Lot less	2 (3.3%)	1 (1.6%)	-	-	-	**3 (4.9%)**
	Little less	-	2 (3.3%)	5 (8.2%)	2 (3.3%)	-	**9 (14.8%)**
	Same	-	-	9 (14.8%)	-	1 (1.6%)	**10 (16.4%)**
	Little more	-	-	10 (16.4%)	7 (11.5%)	3 (4.9%)	**20 (32.8%)**
	Lot more	-	-	1 (1.6%)	2 (3.3%)	16 (26.2%)	**19 (31.1%)**
	Total		**3 (4.9%)**	**25 (41%)**	**11 (18%)**	**20 (32.8%)**	**61 (100%)**

Table 2:
Number of non-first year students who said their confidence and enjoyment of mathematics now was greater or less than it had been during their first year.

These data suggest that those students who make it through to later years of study have on average a more positive experience later than is reported in respect of the first year. Curiously, there was some evidence that students in later years gave a slightly less favourable report of their first year than the current first years. One can only speculate on the reasons for this.

One word of warning though, is that if a student said they felt a lot less confident, say, in year 1, and then rates their confidence now as 'the same' then they are still feeling less confident than they did at school. To try to assess this, we estimated how the students rated their confidence and enjoyment now compared with their pre-university experience. We gave ratings of 'down lots' a score of –2, 'down a little' a score of –1 etc, through to +2 for 'up lots', and combined their ratings for first and later years, so that their confidence and enjoyment now compared with before university is given on a scale from –4 to +4. Although this is somewhat crude, it nevertheless gives us an estimate, which is shown in Table 3.

		Enjoyment					
		≤ -2	-1	0	1	≥ 2	**Total**
Confidence	≤ -2	3 (4.9%)	1 (1.6%)	3 (4.9%)	-	-	**7 (11.5%)**
	-1	1 (1.6%)	3 (4.9%)	2 (3.3%)	3 (4.9%)	-	**9 (14.8%)**
	0	-	1 (1.6%)	6 (9.8%)	2 (3.3%)	-	**9 (14.8%)**
	1	-	1 (1.6%)	4 (6.6%)	3 (4.9%)	4 (6.6%)	**12 (19.7%)**
	≥ 2	-	-	7 (11.5%)	5 (8.2%)	12 (19.7%)	**24 (39.3%)**
	Total	**4 (6.6%)**	**6 (9.8%)**	**22 (36.1%)**	**13 (21.3%)**	**16 (26.2%)**	**61 (100%)**

Table 3:
Estimate of net confidence and enjoyment of non-first year students compared with their pre-university experience.

This suggests a slightly less encouraging picture than the data given in Table 2, but still better than the snapshot of first year experience. We note that

- Encouragingly, 59% felt more confident compared with their pre-university experience, but 26.2% felt less confident.
- Similarly for enjoyment: 47.5% enjoyed maths more against 16.4% who enjoyed it less.
- Two-thirds of the students (67.2%) reported that one or both of their enjoyment or confidence levels had improved since starting university, whereas 29.5% reported that one or both had decreased compared with their pre-university experience. 13.5% felt they had both less confidence and less enjoyment than before coming to university, whilst 39.3% had more confidence and more enjoyment.

Thus it would appear that both confidence and enjoyment levels recover between the first year of study and later years, although there is still a significant minority whose enjoyment or confidence has decreased.

Figure 2 shows a summary of student levels of confidence and enjoyment and reinforces the facts that whilst a majority of students find their enjoyment and confidence levels are the same or better than before coming to university, and despite the fact that there is an improvement between the first year and later years of study, there is still a substantial minority of students in all years whose enjoyment of mathematics at university is lower than their pre-university level.

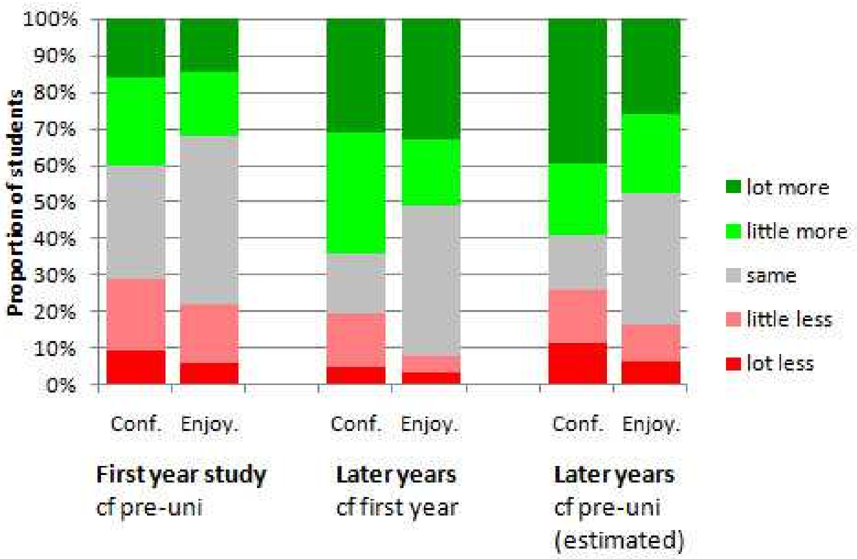

Figure 2:
Summary of student confidence and enjoyment levels in first and later years compared with pre-university and first year experience.

4 Factors affecting student experience of undergraduate mathematics

In this section, we consider the factors that students cite as having a positive or negative impact on their confidence in or enjoyment of mathematics at university.

First, let us consider why these are important to us. It could be argued that a dip in confidence when arriving at university is not necessarily a bad thing; indeed a couple of the students (both reporting confidence down a little but enjoyment up a lot) made this point eloquently:

> *"I learned a little modesty I guess... The course... is constantly challenging me... This is a personal change in my attitude, and not a negative one in my opinion. I believe I was over confident before."*

> *"I am less confident in my abilities as coming to university has made me aware of just how little I actually know. ...The depth and breadth of study at university level is daunting. Not that that's a bad thing, personally I relish my ignorance."*

Indeed, whilst there was – as we would expect - a high degree of correlation between students' rating of their confidence and enjoyment, a handful of students said their confidence dipped but their enjoyment increased. The previous student, whilst feeling less confident, also said their enjoyment had increased a lot.

> *"I enjoy it more because my entire perspective of Mathematics has been shifted. Being taught to think in a mathematically conceptual way rather than simply learning model solutions to exam papers is gratifying."*

However, this positive slant is not shared by many of those students who feel less confident, and from the perspective of encouraging more applicants to mathematics degrees, or indeed our current students' satisfaction, we must surely be concerned at the high proportion who feel less confident, and perhaps even more so, who enjoy studying maths less than previously. Even more importantly, from an educational perspective we must also be concerned at how students confidence and enjoyment translate to understanding, motivation and success; whilst a drop in confidence could prompt either disengagement or renewed effort, a drop in enjoyment is extremely unlikely to encourage students to engage fully with their study, with the consequent effects on their performance, our retention rates, and their feedback to potential future students.

What students say about the factors that affect their confidence and enjoyment is wide and varied; the most commonly discussed issues can be grouped into three categories:

- the style of learning and teaching employed in university, including the standard of teaching and the support available;
- the curriculum content, in terms of the nature, level and amount of mathematics being taught;
- the nature of assessment and feedback.

All three categories include aspects of an issue which has been widely discussed for a number of years, namely the difficulties associated with the transition from school to university study.

Alongside these are a miscellany of comments and suggestions, some very specific to individual universities; some relevant to many more.

4.1 Teaching and learning environment

4.1.1 Large classes and independent study

The switch from usually small classes during 6th form to large lectures was cited as a problem by many students.

> *"Going from 8 in a class to 200 in a lecture makes you feel very insignificant."*

> *"The change in teaching from class rooms to lectures was massive. There is little room for asking questions on points you don't understand in a lecture room of 120 people."*

Students report a variety of corollaries of the standard lecture/tutorial model of university teaching, which many find hard. Many students said that they missed the opportunity to interact with their lecturers as they had with teachers at school, both in individual classes as cited in the quote above, and in the overall amount of contact time.

> *"I found that there was not enough contact between students and academic staff."*

> *"It is a lot harder now and you get less communication with the people teaching you"*

Indeed, the switch to a more independent style of learning is cited a number of times by those whose confidence went down.

> *"[I] didn't have the same interaction with lecturers and tutors as I did at school."*

> *"the style of teaching vastly different."*

It is of course the case that we expect students to be more independent than they were at school, and this causes problems for some, especially at first. One student, who felt much less confident, spoke of being surprised by this.

> *"The structure in which I was taught maths was completely different. I was not expecting it. I felt that it was mainly down to the 'do it yourself' attitude most lectures or seminars have."*

One university in this study offers small cross-module tutorial groups in the first year which were generally viewed positively

> *"I found it especially helpful to have a separate maths tutor with who we had classes in addition to lectures,"*

and in the same university some students found the lack of the same tutorial system in later years a problem:

> *"In my first year although I struggled with my maths and had to do a couple of resits I accepted that I hadn't done enough work throughout the year. Now however I have worked a lot harder and am still struggling. This is very disheartening and makes me believe I can't do it. This year we don't have a tutorial each week, this was one of my main resources for learning and have struggled a lot without this resource."*

Whilst the latter student found later years no easier, many talk about their confidence or enjoyment recovering because of familiarity with university teaching methods:

“The style of teaching is easier after already having a year of it.”

It is also true to say that whilst some find the university teaching structure difficult, others students relish the independence of university study, citing this as one of the main reasons they felt more confident

“The style of teaching is different as more independent work necessary which has helped me improve my mathematical skills and has made me more confident.”

“The very fact that university mathematics is taught via lectures in which there is little or no personal attachment with the lecturer, results in a need for greater individual study.”

4.1.2 Support, contact time and learning environment

The universities – and indeed individual staff members – within this study offer a variety of means of student support to supplement the core teaching activity already discussed, including for example office hours, online support, open-door policies, and drop-in help sessions. Whilst some students perceive problems with the overall structure of university teaching, as evidenced by the quotes given above, many others specifically cite good support from academic staff as one of the reasons for their increased enjoyment or confidence and their related understanding and performance. To some extent this variation may be a result of differences between the universities but perhaps it is also the case that those who have successfully made use of the support available outside classes are more likely to have a positive experience of their first year at university than those who haven’t. Students who said their confidence or enjoyment increased during the first year said:

“I felt I could turn to my lecturers at any time and I was encouraged to ask any queries I had.”

“The friendliness and approachability of the staff was helpful - I always knew I could ask for, and receive, help when I needed it.”

“The lecturers are incredibly helpful and pay attention to us if they notice if we are struggling or not turning up enough. Really supportive.”

“I received a lot of support from my tutors and it really helped me in my first year.”

Two departments in this study run drop-in services offering help with mathematics which some students appreciated:

“Good support was provided from lecturers during the first year, with additional help via Maths Help sessions for anything not quite fully understood,”

whilst others were less positive:

“The drop-in centre is really small and there’s a lot of waiting around even for short questions which is quite off-putting.”

Some students find their experience improves as time goes on:

“I got use to the method finally. I found my own study group... It was a good support system we created.”

It is perhaps worth noting that the latter student believes that the support system was created by fellow students, rather than the department structures. This reliance on fellow students – whether genuinely created by the students themselves or facilitated by the department’s policies – is a common theme of what students say about ‘support’. Many students who had positive experiences talked about informal support networks based on their peers:

“The majority of students on this course get on really well with each other and we do work together quite a lot.”

“There is a strong friendship within the course and we all give help to others who are struggling at the subjects we understand better.”

“I would also say being in an environment with other mathematicians I’ve enjoyed collaborating on projects and also at helping each other with problems, which makes me feel more confident mathematically.”

Perhaps the lesson is that the best means of supporting students is to create a supporting learning environment and facilitate their effective integration into a social and study network of peers – see for example [4, 5, 6].

4.1.3 Standard of teaching

Whilst the problems identified by some students above related to teaching issues, they are not themselves criticisms of the *standard* of teaching. However, some students *did* criticise the teaching they received. We recognise that what some students want from their teaching is not always the same as what we believe is good for them, so we may treat some of their comments here with reservations (this subject is discussed further in [1]). Nevertheless these comments give some indication of the things that students like or dislike. On the negative side, students said:

“I do not believe that lecturers place any importance whatsoever on making the subject <u>interesting</u>” [Student emphasis]

"The first maths module I took was taught via a lecturer reading out maths from an overhead projection, a terrible way to learn maths"

"There's always really disruptive pupils at the back of the lecture hall who make it impossible to concentrate. The lecturers usually waste a lot of time dealing with them."

"First language of the lecturers should be English so they can explain"

Other students were more general in their criticism, and as such less constructive, saying things like

"Some lecturers do not deliver lectures well."

"The standard of teaching at uni is a lot poorer then at school."

"I did not feel that the standard of teaching was at a high enough standard and I struggled because of this."

Some students found the attitude of some academic staff unhelpful, as we see here:

"In the exercise classes, some of the tutors can seem really intimidating (eg repeating the same question to you when it's obvious you haven't got a clue)"

"The lecturers (some) were not very good or helpful, and unapproachable"

We should note, of course, that a student perception of unapproachable or intimidating staff is not necessarily an indication that staff are actually either of these things (and other students in the same institutions may be very positive about the staff), but nevertheless this perception is a potential problem for some students. When students perceive problems with staff, even improved experience in later years is not always credited to lecturers. The same student who found lecturers 'unapproachable' found both confidence and enjoyment increased in later years, but said the reason was

"...better understanding, therefore easier to attack, although I would not put this down to the lecturers."

Where students have a more positive view of staff, their confidence and enjoyment is correspondingly increased. Whilst those above talked about 'intimidating' and 'unapproachable' others were much more positive:

"The teaching has a lot to do with my confidence increasing, I know if I'm ever struggling with anything that someone is always available to help either online or knocking on their door."

One student spoke specifically of the way they felt lecturers treated students well, and the positive effects on the student:

"The teaching style on the course has helped my confidence, the tutors treat the students as equals, I have never been talked down to at [this university]. I feel that the tutors and students work as a team aiming for one goal and that is the students understanding and enjoyment of the subject."

A couple of students talked about staff enthusiasm being a key factor in their enjoyment of the subject:

"The enthusiasm that the teaching staff have for their subject kind of rubs off on you."

Apart from the specific points given above, in general those students who said positive things about their teaching were less specific about what was good than those who were critical. Typical comments included:

"The teaching has been excellent throughout university, and although I have struggled with a few courses but with a combination of guidance from the lecturers, and hard work on my own behalf I feel that I have overcome most of these difficulties."

"The biggest reason [my confidence increased] is the support I have received from most of the staff but also the style of teaching on the course."

We could perhaps conclude this section about teaching and learning from the student perspective by pointing out that what students talk about is not, primarily, in terms of the 'structures' that we might put in place to support and teach them, and not even (very much) about the style of teaching itself, but rather mainly about their desire – need? – for a level of human interaction in the process, with both staff and fellow students; what has sometimes been called a 'community of learning'.

Elsewhere [4, 5, 6] we discuss some of the means in which staff have tried to encourage the development of such communities in their departments.

4.2 Curriculum content

Let us start this section with a blunt statement from one of the students in our survey:

"I enjoyed Maths less because I found it too hard."

A number of students talk about the difficulty of dealing with mathematics which is harder than at A level. There would surely be something wrong with a maths degree which was not harder than A level study! But the quote above raises questions about the difficulties which students face. Is the problem caused because of a sudden jump in level that could be eased by better 'transition' arrangements? Is it caused by problems at A level leaving our students ill-prepared (and if we take this tack, is it students who are ill-prepared, or us that have unrealistic expectations of them)? Should this student have been accepted on a mathematics degree if they would be unable to cope with it? Do some students reach a limit to the level of mathematics they can cope with, which can't be predicted from their A level performance? Does the nature of the maths which is taught change substantially at university – and if so are students aware of this before they arrive? How do they cope with it when they do? Were the student's expectations of university maths unrealistic? Is the maths, as this student says, simply too hard?

A number of students make the point that finding mathematics hard is a new experience to them, and that they are unused to needing to work hard to get to grips with it.

> *"The mathematics has become much more difficult and requires a lot more work for me to understand than A Level mathematics"*

> *"At A level I found that although the maths was challenging I never came across things that I truly struggled with. Since being at university I constantly come across things that I don't have a clue about. There seems to be a big jump between A levels and uni, and even between years in uni."*

It is perhaps particularly important for staff to remember this; those of us who progressed from A level to undergraduate mathematics to doctoral study and into the profession are the least likely to have ever experienced the sheer frustration of not 'getting it'. For many of our students, A level was well within their capabilities, and faced with challenges of university mathematics, some are having to deal with a lack of understanding which is unfamiliar, and as the following student points out, the frustration can seriously affect their experience.

> *"[I enjoyed maths a lot less in my first year because] I did not understand some maths at all, which led me to become very frustrated."*

Some students are able to cope with this without the frustration. The following student said they felt less confident but viewed this as a positive sign of the increasing demands being made of them.

> *"Mathematics at university requires a lot more study. Whereas at A level you could almost not need to revise if you understood the material, because it was simple to know. Now the mathematics is a lot harder and more challenging, so I am a bit less confident in a good way, as the mathematics is progressing into higher levels."*

Some students are still more positive about the challenges of university maths:

> *"The complexity of university mathematics combined with the workload have significantly improved confidence in my mathematical abilities."*

In other words – no surprise here – you can't please everyone! Even the student quoted earlier who talked about becoming frustrated, enjoyed the subject more in their later years.

> *"I am beginning to understand a little better, and enjoy the challenge now, rather than becoming frustrated."*

The question for staff, of course, is how we can encourage our students to enjoy the challenge before the frustration becomes too much for them, at which point it is perhaps appropriate to consider the specific aspects of curriculum content which students cited. Opinions are – inevitably – divided about the aspects which they see as good or bad.

A number discuss the use of the first year of undergraduate study to revise and consolidate ideas from A level; the first quote here suggests that there was no revision of A level topics:

> *"I think maths lectures assumed a complete understand of A-level, and it was sharp,"*

whereas others agree that there was substantial revision but disagree about whether it was appropriate.

> *"There was a lot of repetition of content covered in A levels which made it tedious and frustrating. At times I did not feel my mathematical ability was being improved by being at university."*

> *"I felt more confident because the first year material was mainly revision work from previous study up to that point; only a few new topics were covered. For that reason, i felt more confident - for that level of the work."*

> *"Very boring as did not study anything new [in the first year]."*

Having seen the syllabi for the four universities, we find the last comment implausible but nevertheless it is discouraging if students are getting bored in their first year.

In addition to revision within core modules, the universities in this study generally offer some support to weaker students (or those who have had a gap in their education) in the form of workshops, additional modules, drop-in centres, etc. Student comments on this are mainly included in the section above on student support, but the following comment is worth noting in relation to curriculum design:

> *"Catch-up classes were done, but these were over a 9 week period. It would have made far more sense to do the catch lesson* ***then*** *start the course, as the course built on understanding the catch-up classes."*

One aspect of the difficulties and challenges of university mathematics is that the nature of the mathematics, and our approach to it, changes. For example, on the question of whether mathematics can be tackled using an algorithmic approach, one student felt less confident because

> *"I found it a lot easier when most mathematical questions could be answered by simply recalling and applying a formula. This is no longer the case at university level mathematics,"*

whilst another felt their confidence had increased for related reasons:

> *"At university, we learn mathematics in such a way that we understand what we are doing and apply these skills to answer questions. However at sixth form we just do maths until [we can] answer questions without really understanding."*

A similar point was made by a student whose enjoyment had increased on arrival at university

> *"Before hand it seemed, more learning methods of how to solve questions rather than learning* ***real*** *maths."*

We know that university level mathematics is more rigorous than school maths, and some students specifically cited this as their main reason for increased enjoyment.

> *"We started to learn maths rigorously and I found I had more opportunities to apply my knowledge in problem solving which is far more satisfying than just jumping through hoops."*

> *"Most of the mathematics that we learnt in the secondary school were applied mathematics. When you come across with notions such as 'convergence + continuity' or 'countability' at university you felt like a mathematician, and then the real journey starts."*

Unfortunately, some find that journey robs them of the enjoyment which they associated with mathematics.

> *"It is becoming harder and there are theorems and proofs to learn and definitions, its not the same as before where we just had problems to work out etc which was fun."*

Analysis in particular provoked both positive and negative reactions, relating to the novelty of this style of mathematics compared to their prior experience.

> *"[My confidence went down because] the type of maths I was learning was so different to A level and GCSE maths, for example the module Analysis was totally different from anything else I had previously done, and so I found that module quite difficult."*

> *"[My confidence increased because] the content of the course, particularly Analysis, provoked me to develop or perhaps hone a more precise technique of mathematical analysis. It meant I was more able to create my own problems and understand more complex problems than before."*

> *"The main reason for [my decreased enjoyment] is Analysis module which really affects my interest in learning maths. I do not have a clear idea about the purpose of studying it."*

We note about the last quotation that it is not the Analysis per se which affects the student's enjoyment, but that they cannot see its relevance. Indeed, the question of relevance to 'real life' and the level of abstraction in some modules is mentioned by a number of students; some see university as more abstract than school maths whilst others see it as more closely linked to 'real' problems. Whilst they do not agree about whether it is more or less abstract, the comments made are generally negative about abstraction and positive when they see more relevance to future work:

> *"The content of some modules is really abstract, I think it would be helpful if there were more examples we could actually relate to, so we could learn it more by association first rather than definitions."*

> *"There is just such a greater diversity to the maths I am doing now. It's much more interesting to work with real situations, even it they are very basic at the moment, that to only deal in abstract maths, as it was before coming to uni, with only the vaguest idea of what any given topic could be applied to."*

> *"Much more interesting and it covers lots of things very relevant to life. eg modelling a battle and option prices."*

> *"I enjoy it more as this course is more than just the maths. We include technology and relate the work to actual aspects of life therefore a purpose of mathematics is included."*

The above collection of student views point to an obvious truth widely accepted by academic staff; namely that the nature of university mathematics can be very different from that which the students are used to, in all sorts of ways which students can find discouraging or encouraging. As at most universities, staff at these institutions have given considerable thought to the question of 'transition' to university mathematics but some students felt that more should be done to help students learn about what, to them, is a new style of maths.

> *"They didn't teach us how to learn maths at uni, but only told us what we had to learn."*

Two particular issues raised by a few students were over the introduction to the idea of proof, and to the notation used at university.

> *"The notation used a uni is like a foreign language compared to A-level maths… It was not taught before we started, and would only be explained by the odd interruption in the lecture, whilst you're trying to figure out everything else."*

"Everything seemed a lot more formal, i.e. notion of rigorous proofs and also the fact that a lot of new notation was taken as a given."

"[I] did not understand proofs etc or notation used, and no explanation was given."

"At first I found it very hard to construct proofs as I had no prior experience with them and felt as though there wasn't enough help to adjust to this style of mathematics."

Our conversations with academic staff support the view that students do not have well-developed skills either in creation of proofs or mathematical writing, and yet what is notable about all the comments above is that students point to a lack of explanation, or a lack of time devoted to developing their skills in this area. Of course, many students succeed in developing these skills nevertheless, and one quoted above whose confidence recovered in later years said simply

"I have adjusted to higher level mathematics now."

A number of students, particularly those from later years, cited the course structure, with very little or no choice in the first year, as one fact in their decreased enjoyment of mathematics when they first arrived at university.

"Due to the wide areas of maths covered in order to provide a foundation for the rest of the degree, I had to study some areas of maths which I found boring."

"I felt the course was too restricted ie too many compulsory modules"

"All my first year modules were compulsory so I did not get to pick any that interested me."

"Courses were quite abstract and felt like they were there only to teach us the foundations that are needed in later years, as opposed to modules which were interesting in their own right, which many of them could have been."

The last comment is worthy of note, insofar that the student did not question the need for foundations, but felt that these could have been taught in a more positive way.

Many of the same students found that as their student career progressed, they were able to focus on topics which were of more interest to them and both confidence and enjoyment improved as a result.

"I am finally allowed to study modules that I am interested in."

"[Being] able choose some options which are helpful as you can choose what modules you prefer rather than what you have to do."

"Being able to study which parts of maths I want."

"I am studying topics which I am interested in and I enjoy"

"Modules now feel like they are taught for interest/enjoyment and especially in applied mathematics, you can see many examples and applications to real situations"

Student views, then, on the curriculum content of courses cover many aspects: the level of difficulty of the work and the transitions - particularly from A level to undergraduate level but also at other levels; how much revision there should or shouldn't be; the overall workload; the changing nature of the mathematics compared with previous study; the relevance of what they are studying; the introduction of new ideas and notation without sufficient development time; the amount of choice in the curriculum, amongst others. That there is no clear agreement amongst the students is perhaps unsurprising, given the diversity of the students surveyed. These issues of curriculum content and more generally the nature of mathematics at university are topics which staff continue to grapple with. Elsewhere [7] we discuss some of the issues around curriculum content.

4.3 Nature of assessment and feedback

In the 2009 NSS [2], the questions about the timeliness, detail and helpfulness of feedback on student work suggest a picture of dissatisfaction amongst students, at least in comparison with most other aspects of the course. In fact, averaged across all subjects in England, the three statements "I have received detailed comments on my work", "Feedback on my work has helped me clarify things I did not understand" and "Feedback on my work has been prompt" scored the lowest proportion of students in agreement. In the average scores for mathematics courses students were generally more in agreement that feedback had been prompt, but the questions about the detail and helpfulness were, as with other subjects, ranked lowest. This was also true of the three institutions in this study with NSS returns.

Against this background we might have expected dissatisfaction with assessment and feedback to feature more prominently in the comments that students made. In fact, it was cited relatively rarely in relation to their confidence or enjoyment of mathematics (although they had plenty to say about it when we asked about possible improvements to their course – see [1]). That said, some students did talk about a lack of feedback at university as a particular cause of their drop in confidence.

"I felt lost without constant assessment and feedback as at school, and failed several modules."

"[There is] not as much assessment and opportunity to gain feedback; therefore no feeling of achievement or progress. The amount of assessment within school maths provides instantaneous rewards."

"Harsh criticism"

Some students talked about positive feedback in a general sense having an effect

"The feedback that I have had has improved my confidence,"

but rather more cite specifically good marks, rather than formative feedback, as a reason for increases in their confidence.

"My first year results increased my confidence, and getting into the swing of the style of assessment and teaching, generally settling in, helped increase my confidence."

"Having received marks for my first year and January exams of second year has caused me to feel more confident."

"I've been getting good grades in tests and courseworks, and I feel like I understand the topics a bit better, and enjoy it more."

"High grades made me more confident in my abilities."

Unsurprisingly, the converse reduces confidence.

"My average exam score has dropped by about 30%. And I can't necessarily answer every homework question immediately"

Students do not solely rely on feedback from their tutors, of course; they also make judgements about their own abilities based on comparison with their peers. This would appear to have entirely predictable effects on their confidence, with relatively weaker students feeling less confident:

"It was expected - simply being in a group of people who had higher maths ability than I did."

"I find the mathematics very hard to do, while my peers seem to breeze through."

and stronger students feeling reassured:

"[My confidence increased because of how] I compared to other people on my course."

"...my exam results were way above average for the year, and I realised I'd already studied most of the course during my Further Maths A level"

"Throughout the many modules I felt I had an understanding at least as much as most others around me."

In short, then, in relation to their confidence and enjoyment, students report an entirely predictable result: if they receive positive feedback from tutors, especially in the form of good marks, or if they judge their progress to be good compared with their peers, they feel encouraged. Poor marks, negative feedback or an uncomplimentary comparison with their fellow students have the converse effect. Poor NSS scores for feedback will no doubt give departments and universities added impetus to try to improve feedback to students. Elsewhere [8, 9] we discuss issues relating to assessment and feedback and the ways the universities in this study have approached these, and in [1] we report what students say needs to be improved in relation to feedback.

5 Discussion and conclusions

In this paper we have specifically focussed on what students said about their confidence and enjoyment of undergraduate mathematics. If these two factors were not important enough in themselves, we anticipate that our colleagues will share our view that confidence and enjoyment are intimately linked with students' motivation, understanding and performance. As such, we believe the results of this survey should be of interest to anyone who is interested in the overall educational experience of our current students, or in our project aim of encouraging more students to study maths, or indeed has a more cynical eye on future NSS responses.

By getting open-ended answers from students, the issues which emerge are, we hope, a reflection of what they view as important factors, relatively unbiased by our own expectations; it is, we might say, "from the horse's mouth".

A number of thoughts and questions emerge, which are summarised below. We do not presume to attempt to give colleagues the answers – we do not believe ourselves to be experts and in any case every university and course is subject to different circumstances. However, where the theme is taken up in more detail – for example discussing some of the approaches taken by our colleagues in our or other institutions – in other publications from the more maths grads HE curriculum team, we have given references as appropriate.

- Student experience of undergraduate maths is, of course, varied. It is varied across institutions, and within them. In almost every question we could ask of students, there is a range of opinion. This is, we are sure, not news to anyone who works in HE. However, this obvious truth bears repeating often and to the widest possible audience, lest we fall into the trap of assuming all our students are lazy/brilliant/like us/ill-prepared.

  Dealing with this diversity presents difficulties for universities and HE staff. Whilst we talk about 'independent learning', and despite much hyperbole about more flexible models, in truth within most institutions, our model of teaching and learning is more of a one-size-fits-all approach. However, there is much more variation generally between universities than available within any one institution. Whether these differences are appreciated by potential students is debatable. We hope our booklet Maths at University [10] may help students to make the right choice for them. Nevertheless, diversity within the student body will continue to present a challenge for staff
- One aspect of the diversity of student experience is apparent in what they say about the level of difficulty associated with undergraduate mathematics. By 'difficulty' we might include the overall workload, as well as the intellectual challenge associated with getting to grips with the subject matter. Some relish the challenge; some feel lost and at sea. The question for staff is always: are we pitching our courses at the right level? Is our subject's reputation for being hard something we should protect and maintain, or is it, as a student we quoted earlier said, actually 'too hard'? [7, 11]
- It is of course inevitable that there will be students who do less well than others. For any student, unfavourable comparisons with their peers (whether made according to their perception of how much they understand in comparison with their friends, or the marks or feedback we give them) can be disheartening. A particular problem may be apparent on courses where the entrance requirements are high. These students were - most likely - the better mathematicians amongst their peers at school. Some will find the move from being top of the class to bottom difficult and frustrating. From the perspective of wanting to increase the number of mathematical graduates, these students present a particular challenge to academic staff. They are more mathematically able than most people, they chose to do maths, they had perhaps straight A grades at A level; in short they are people who should be happy successful mathematicians, and yet by going to a university with even more able students, their overall experience can be a very unhappy one. To what extent can the weaker students on a particular course, who are nevertheless relatively able mathematicians, be encouraged to continue and flourish in their studies? [4, 8, 9]
- Students generally view contact with staff – formally timetabled or informally – as vital to their positive experience. We would be surprised if most teaching staff did not agree, yet experience suggests that our classes get bigger, our staff numbers decline, and university accountants believe the gap can be made up by being more efficient and using the occasional computer-aided teaching or assessment package. Many staff in maths departments have indeed explored the possibilities of using advances in IT to change the way they teach and assess – see for example [12, 13] – or maintain contact with their students – see for example [14]. For a discussion of the use of timetabled contact time in the partner institutions from the MMG work, see [15, 16].
- Where students feel they have found effective support – whether from staff or from fellow students – they are generally positive about their experiences. However, not all students appear to find their own community of learning within their universities. Staff can and do try to encourage formation of students support networks, and access to staff help, in a variety of ways – see [4, 5, 6] for example.
- The question of 'transition' is raised by students, in a number of guises. This has, of course, been the subject of much discussion within the mathematics community in recent years, with a focus primarily on the notion of 'bridging the gap' between students' mathematical knowledge and skills on arrival, and what we think they need to know to study at university. In [17] one approach to this is discussed, whilst in [7] we consider more fully how curriculum designers might respond to students' abilities on arrival.

- It is notable however that what students say about 'transition' is not limited to, or even focussed on, the idea of a gap between school and university curriculum content. Indeed, their discussion of the merits or otherwise of A level revision at university suggests that they do not perceive a gap in these terms. In terms of a mathematical gap between school and university, students talk more about the nature of mathematics and our approach to it (for example, in notation, approach to rigour, and abstraction), and cite little time or effort devoted to developing these skills and attitudes. If we view these as important, is this reflected in how we teach? See [18] for one approach to encouraging students to develop the skills of a professional mathematician.
- Students do talk about a 'transition' issue in terms of the overall difficulty of the work. They do so across all levels (in line with evidence from elsewhere about shifting 'transition' problems into later years – see for example [19]), not just talking about an increase in difficulty between school and university. We note that it would be odd if things didn't get harder as students progressed, but also note that a perception of difficulty may be a reflection of the work itself, but may also be a reflection of how well the student is coping with other aspects of university life, such as the shift to more private study. Indeed, the change to independent study, large classes, and less staff contact time is one of the major issues related to 'transition' to university life that students mention.
- Students also talk about difficulty getting used to different styles of assessment and feedback. In other words – transition issues again, which cross the whole range of the student experience.

Finally, we note that to a large degree, the themes raised by students are reflected in the issues which appear to be of concern to HE staff, judging from our interviews with selected staff at four institutions, and from the plethora of literature relating to undergraduate maths practice including, for example, those published through the journals and conferences of the Maths Stats and Operational Research Subject Network. We could conclude, perhaps, that staff seem to know pretty well what the issues are, and are attempting to tackle these in many diverse ways, but the fact that the same issues are still be raised by our students means that we cannot yet be fully satisfied with our own efforts.

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3.2 *From the horse's mouth 2: The best of times, the worst of times…*

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1 Introduction

Our students are a mine of ideas about what is right or wrong about our courses. They are rarely short of suggestions about what should be changed, and how.

It is, of course, a debatable point whether what they suggest is realistic, financially viable, or - crucially - educationally sound. This question is something to which we shall return later in this paper. Even putting it aside for now, it is undeniable that with longstanding university procedures for measuring student satisfaction, and even more so with the more recent introduction of the National Student Survey (NSS) [1], we ignore what students say about our courses at our peril.

As part of our data gathering for the More Maths Grads project we surveyed students from all years across four diverse institutions seeking their views about their experience to date. The survey methodology and some results relating to the overall student enjoyment levels are presented in [2].

In this paper we report three related aspects of that survey, in the form of direct quotations from the open-ended questions that we asked. The three questions were

- 'Thinking about your experience of studying mathematics at university, what has been the best or most useful thing for you personally?'
- 'Thinking about your experience of studying mathematics at university, what has been the worst or hardest thing for you personally?'
- 'Please tell us three things that would improve your course.'

For the first two questions, we gave no additional prompting about what aspects the students might consider (although we note here that this question had come after previous questions about their confidence and enjoyment of mathematics so certain aspects of provision would perhaps be at the forefront of their mind – see [2] for details). For the third question we gave some additional suggestions about how they might answer the question – see Figure 1.

Please tell us three things that would improve your course.

Your answers could be about: the overall course design, the curriculum content, the assessment methods, the teaching methods, the organisation or the course, or any other aspect which the department could change in the future.

(The more constructive you can be, the more chance there is that these changes will be made in the future! Suggesting "abolishing exams" or "individual tuition for all students" is unlikely to produce change)

1.

2.

3.

Figure 1:
Three things that would improve your course, showing the full text of the question.

As a result, in this paper we collect together student comments on what is good, bad and in need of improvement in their course. In the final section, we consider more fully the question of how staff might proceed where they do not concur with the student view.

2 The best and worst aspects of studying maths at university

When we asked students, in an open-ended question, to tell us what had been the best or most useful aspect of studying maths to-date, and the worst or hardest aspect, they gave us, as you might expect, a wide and varied set of answers. Many of their responses followed the same broad issues raised in [2] as affecting their confidence and enjoyment, and indeed these issues are largely along the same themes as education professionals have been and still are considering. In addition there was a range of comments ranging from their own personal development down to module-specific problems.

A high proportion of students cited the support they had from tutors/lecturers as the best thing about their course. The following quotes illustrate the sentiments expressed:

> *"Personally It's the help from tutors and lecturers that has been the most useful, I have always enjoyed maths but not necessarily been that good at it, therefore the help I have received this year has been fantastic in helping me to increase my mathematical abilities."*

> *"The professors are the most important aspect of studying. If they are enthusiastic and friendly, but are strict enough to be respected, that makes studying a great experience."*

> *"The lecturers have been quite approachable about any problems I may have. Talking to academics about maths is probably the best part to studying maths at university."*

> *"I think the lecturers have been the most important thing. They have been really helpful and consistent with their teaching."*

> *"How encouraging and motivating staff are at helping me to achieve highly."*

Unfortunately the positive view of the teaching staff is not universal; a (smaller) number of students cite the quality of teaching as the worst thing about studying maths.

> *"Some of the lecturers do not provide the support they should been providing or do not provide it at all."*

> *"Lecturers who seem unorganised and don't have the class under control!"*

> *"Having an interesting subject ruined by bad teaching."*

It is perhaps worth mentioning that the mainstay of university teaching – the lecture – is rarely mentioned specifically (although obviously the above comments about lecturers is to some extent a reflection of the student experience of lectures) and when it is mentioned, this is as one of the worst aspects:

> *"Lectures - others talking is very distracting, trying to concentrate and take notes simultaneously is beyond me leaving me with only notes I don't understand until they are explained to me."*

Tutorial/example classes, on the other hand, are widely cited as the best thing about studying maths, and where universities offer additional drop-in sessions these are also mentioned.

> *"Tutorials going through the maths questions which I didn't understand, to help show the path instead of just the answer."*

> *"I think that the most useful thing for me this year has to be maths help."*

As discussed in both [2] and [3] many students gain support not just (or even primarily) from their tutors, but from their peers. For students who have successfully built a social and support network, this can be their best experience of the course:

"The strong friendships built which have given me an excellent social life as well as a group who I can rely on for help, and who can rely on me to help them."

"How encouraging fellow students are"

For some, however, a lack of social and support networks has been the worst aspect:

> *"I haven't made as many friends as I would have liked on my course, I think this is a very important factor."*

> *"Not having a class like at school, knowing everyone's name, and so working alone the whole time."*

Assignments, assessment and exams get a mention both as the best/most useful and worst/hardest aspects. One student said

> *"The assignments have been great. They really built confidence and were quite a lot of fun to do,"*

and although no others talked about them being 'fun' there were other comments recognising their usefulness, especially where the work was marked.

> *"Assessed homework sheets, ensured content was known and understood before final examination, helped to consolidate understanding and highlight any misunderstandings."*

One student felt there were not enough assignments, saying the worst aspect was:

> *"fewer homeworks, means less driven to work,"*

but this was heavily outnumbered by the students who found the workload overbearing.

> *"The hardest thing has been the workload and the pressure piled upon us to achieve a good pass mark in the first year to avoid resits and extra exams."*

> *"Very intensive course with long hours."*

> *"Getting used to all the work we have to do."*

Some students talked about the workload being the hardest aspect of the course, even though they viewed this in a positive light:

> *"There hasn't been a worst thing, the hardest possibly is having about five different deadlines at once, but I'm never one to give up on a challenge and have always managed to meet the deadlines and hand in a piece of work that I have tried my very best with."*

Whilst the above comments relate specifically to assessed work, numerous comments were made about the workload overall and, perhaps closely related, the challenge of studying a difficult course. The transition from A level to university is mentioned as a particular difficulty:

> *"the hardest thing was the transition from A level to Degree level,"*

as is the transition from first through to third year:

> *"the worst thing this year specifically has been the work load. It was a big increase from the first year which was a big shock to me. It has been difficult, but now I am near the end of my course it does seem worthwhile,"*

and even for 3rd to 4th year:

> *"[the hardest/worst thing was] making the step up from 3rd year modules to 4th year modules."*

Students may find the work demanding, but cope with it nevertheless, whilst for others the challenge is so great as to be demotivating. Lack of understanding is cited by a few as their worst or hardest aspect

> *"Not understanding things leads me to be demotivated."*

> *"Certain modules are quite hard, and I feel like I do not understand it at all."*

> *"Overcoming thinking that I couldn't do something and being disappointed with certain grades-picking myself back up and trying again."*

> *"The worst thing for me is when I simply cannot answer a question by myself."*

That said, some recognise the positive benefits of the struggle

> *"The worst part is when I'm not really understand some topics and I can't do the assignment. That is the hardest part of it because sometimes it pressures me. Anyhow, it makes me put in extra effort though."*

A rather smaller number cite the challenge as the best aspect of the course:

> *"The challenge of university mathematics."*

> *"Understanding difficult material is rewarding"*

> *"The maths has been new and challenging, which has been enjoyable."*

Similarly in just a few words, some students give a very positive view of their experience of studying maths. The best thing was, they said:

> *"Intellectual stimulation."*

> *"Mathematics has always been a passion of mine and having the opportunity to study it full time has been fantastic."*

> *"I am studying something I enjoy."*

> *"Maths is very complex and can be very exciting."*

Unfortunately, not all students share that excitement, either generally:

> *"I never found the things I learned interesting, and that by far is the hardest thing to get use to,"*

or in specific modules

> *"Doing modules which you have no interest in. You don't put in as much work and consequently do worse in the exam."*

The preceding comments relate to the learning, teaching, support, assessment, workload and to a lesser degree the curriculum content of mathematics courses, but a number of students were more general in their description of what they found best or more useful. Key skills, whether specific to mathematics courses or more generic, and personal development were widely cited as the best aspects of their course. A number of students talked about becoming more independent:

> *"Individual study has been the most useful thing and also the best for my character development."*

Others said their confidence had increased:

> *"Becoming more confident in myself as a person, about my abilities and having a better attitude to being able to do something."*

> *"The increase in my confidence as a person, before I came to university I was very shy and had no self confidence at all."*

> *"The presentation has really help[ed] the confidence of myself with other people."*

Some talked about learning to face challenges:

> *"Learning to work through problems for quite a lengthy period without giving up. Greater feeling of satisfaction."*

> *"Maths has been a hard challenge for me over the past two years so I think it has shown how hard you really have to work to get somewhere."*

A number talked about enjoying developing their problem-solving skills

> *"Building on my problem solving skills and being creative with ways to overcome a problem"*

> *"The best thing for me personally would be breaking a very challenging problem into smaller pieces, spending some time on it and getting the right answer."*

> *"Solving problems by myself rather than just following a laid down method was very satisfying."*

For some students, the development of their ability to think analytically was the best thing, whether applied to mathematics or to other aspects of their life.

> *"Overall be able to think about many aspects of life in an analytical manner."*

Other key skills which were mentioned more than once included improved time-management, and IT skills.

Finally, if all else fails, there is always love:

"I don't have anything specific relating to mathematics, but being on this course has helped me find a girlfriend!!!"

3 Student ideas on improvements which should be made

We asked students to give three ideas on how their course could be improved. The answers were open-ended but there was some guidance about the aspects which they might like to consider (see Figure 1).

By far the greatest number of responses related to coursework (whether assessed or not) and feedback; this is in line with the NSS results where – both for mathematics and averaged across all subjects - questions relating to feedback generally score badly. Amongst the suggestions are having more coursework; having less coursework; having smaller more frequent assessment rather than large assignments; having larger less frequent assignments; providing better feedback; providing quicker feedback; making coursework count for more towards module marks (including suggestions to make the assessment entirely coursework based); and spreading the workload more effectively between modules.

Clearly some suggestions are apparently contradictory (although note that contradictory responses sometimes come from different universities where the coursework regime is itself different). Insofar as it is possible to draw any conclusions from this, it would appear that students favour little-and-often coursework with rapid feedback provided not all module lecturers set work at the same time.

Being able to get some kind of feedback to assess their work is also reflected in another common suggestion; namely the desire for solutions to be made available for both coursework and past exams. Whilst lecturers (including the authors of this paper) may be reluctant to supply model answers to exam papers, for a variety of reasons, many students view this as desirable:

> *"Access to solutions for exam papers would be very useful. At the moment when we practice for exams we don't know if we are getting it completely wrong."*

The second highest category of suggestions was related to tutorial/example classes. The specific suggestions varied from university to university, but overall they could be summarised as students wanting more contact time, at higher staff:student ratios.

Students are forthright in their opinions of the quality of teaching, and some of the suggestions are general

"more enthusiastic lecturers,"

"more inspirational lecturers,"

"give lecturers better training,"

whilst others make particular suggestions about how the teaching should be improved

"Less content in lectures, it's ridiculous how much you cram into fifty minutes."

"Clearly structured lectures, showing methods and examples, and stating which they are doing."

"More worked examples done in lectures"

A number of students suggested means of putting their learning into perspective, for example:

"(Very) short written explanations about each chapter/topic within a module, their uses, and the part they play, so to speak."

"More explanation of what the courses involve, for example a seminar on the courses, since without actually doing the course it is hard to know what to expect from it."

In all four universities in this study it is common, but not universal, practice for lecturers to make lecture notes available online. A substantial number of students believe this should be done in all modules

"More course materials! All courses should have a complete set of lecture notes on the web."

Some suggest more innovative ways of providing backup for lectures.

"The pilot scheme for interactive online resources was/is a very good idea, with videos working through particularly difficult or confusing questions, just so that students can replay it again and again. Often you understand in the lecture when something is said, but you get back home and no longer understand. A verbal explanation is often better than a written one."

"Lectures being recorded and posted online (e.g. You Tube) for future viewing like Yale has done for example."

There were numerous suggestions about the course structure, ranging from a desire to avoid specific modules (Analysis and Statistics are both mentioned a few times) to a widespread desire for greater choice in modules.

A handful of students had opinions about increasing the interaction between students, particularly across different levels. These included

"Include some kind of group project as currently everything is done on a solitary basis."

"Allowing third or fourth year students to be first year tutors or to run the first year workshops as I think it would be beneficial to both parties."

"More social events in freshers [week]."

Similarly, some students wanted more of a taste of the other work of the department.

"Perhaps a few 'fun' lectures on research being done in the department."

Of course, many staff will have considered already the ideas raised by students, either from our own initiative or in response to student feedback gathered in the department. Where we have not provided the system students suggest, we may have very good reasons for this. How we should deal with this situation is considered further in the conclusions section below.

4 Conclusions

Many of the issues raised by students in their answers to the questions about the best/worst aspects of their course and the areas where they would like to see changes reflect and reinforce evidence from elsewhere, reported for example in [2], in other publications from the MMG HE team [3, 4 and many others], in the NSS [1], and indeed from other sources including university's own module review questionnaires.

Where the issues raised have already been discussed more fully in [2] we shall not repeat the detail here, but think the main issues raised are significant and important enough to bear some outline repetition. In addition there are issues raised in this paper that were not discussed fully in [2] and these bear some more detailed discussion here.

- Successful creation of a social, study and support network of peers is key to many students' ability to cope with the demands of university life.
- One step removed from the students' immediate network of peers, there is some evidence of students seeking what we have called elsewhere a 'community of learning' within their departments, with encouragement for peer assisted learning programmes, social events within the department, group projects and more appreciation of the departmental research work.

- Transition to higher levels of study still causes problems for some, despite efforts in all universities to tackle this problem. This issue is not restricted to the transition from pre-university to first year study, but rather reoccurs at all levels of study. Viewing transition problems as being something which only relates to the first year of study would be a mistake.
- The challenges of university mathematics are something which some students relish, but some report a lack of understanding in their studies with associated disheartening effects. Whilst this is reported by a minority of students, one might speculate on whether this disengagement and lack of understanding should be so widespread and noticeable, particularly on courses with high entry requirements. Is the level we demand of students appropriate to the students we are admitting?
- The single biggest aspect discussed by students when we asked them to suggest improvements to their course concerned assessment and feedback; this is in line with findings of the NSS averaged across all subjects as well as looking specifically at mathematics. Perhaps it is inevitable that a generation of students who have been tested so much at school will find the more hands-off approach at university difficult at first. With declining staff-student ratios in many departments, it is also one of the hardest aspects for staff to improve upon.
- Related to this, many students are seeking the means – through the provision of model solutions – to assess their own performance in other ways. We note, of course, that as a 'real mathematician' they should perhaps be able to assess their own solutions by some means other than reference to their tutors' solutions. Nevertheless, we can see that appropriate use of model solutions can be extremely beneficial to the learning process, and demands for them by students will no doubt continue.
- Similarly, many students would like to see lecture materials available online – whether as conventional notes or as recordings of lectures (see [5] for a discussion of this latter idea)
- Students, by and large, value interactive contact time with staff. We note, for example, that lectures are never mentioned as the best aspect of the course, whereas tutorial classes frequently are.
- On a related note, it is significant that students talk about their relationship with lecturing staff frequently, in relation to both the best and worst aspects of their course. Clearly, students appreciate it if they find the teaching staff friendly, helpful, encouraging, approachable and enthusiastic. Some students however, find some staff to be none of these things.

This latter point brings us to the key discussion point of this article, which combines aspects of two key points: namely how we respond to student suggestions for improvement, and how students and staff relate to each other.

As teaching professionals we are no strangers to module questionnaires, teaching quality assessment, peer review etc. The National Student Survey is the latest addition to the means of assessing our performance. The feedback we get from our students includes

- some suggestions on which we agree that we should act;
- others which are contradictory – how could it be any other way when our students are a diverse bunch?
- impractical ideas – for example most staff would like better staff:student ratios but university accountants don't seem to agree
- requests which are of doubtful educational merit.

In the same way, the suggestions for changes made by students in this paper may be deemed to fall into all four categories. We present their suggestions, therefore, mainly in the spirit of raising the issues of concern to students; and in the knowledge that committed teaching staff will no doubt continue to grapple with the difficulty of deciding the best route forward. However, we consider it worth a brief discussion on how we deal with the circumstances – corresponding to the latter three bullet points above – where it may appear to some or all of our students that we are being unresponsive to their demands.

Let us consider, for example, the provision of online lecture notes – something which many students desire and none are likely to object to. Staff – including the authors of this paper – have differing attitudes to this. Arguments in favour of supplying them might include: ensuring students have an accurate set of notes; enabling students with non-university commitments to study from home at a time of their choosing; freeing time during lectures which would otherwise be spent creating notes in favour of something more productive. Arguments against include: supplying notes encourages an attitude that lecture attendance is optional; notes created by the student are more personal and therefore more effective to their learning; creating notes during lectures is one way of ensuring that students are engaged with the lecture. (For a fuller discussion of these issues, see [4].) The reader will no doubt have made their own decisions on this issue in relation to their own teaching. If your decision is that you will not supply notes to students, how do they react to this decision?

We propose that most of our students will forgive us most of our decisions – indeed, they may even come to approve of them – providing we develop with them a full and frank educational relationship; that is to say, we treat them as partners in their own education. Given their personal and mathematical developmental stage, they are, initially at least, junior partners, but we can still explain the reasons behind the decisions we make, and remain sufficiently open-minded that we may change our practice in the light of discussions with students (this presupposes that they have the opportunity to discuss it directly with us).

We see this as having a number of positive benefits:

- Students feel valued and part of a 'community of learning' which includes fellow students, tutors and lecturers. There is substantial evidence – see [2, 3] for example – that this inclusion helps student engagement in their education.
- By encouraging a genuine and open dialogue between ourselves and students as partners in their education, they come to see us as rounded human beings rather than distant and 'other'. As such, we encourage students to see staff as approachable and so enhance their opportunities for seeking help.
- Furthermore, these discussions encourage students to consider their own learning styles and reflect more effectively on what works for them, and this engages them more fully in their own education rather than expecting to be passive (and sometimes disgruntled) recipients of what we dish out.
- A genuinely open-minded discussion with students may, of course, result in our making better decisions.
- Finally, by engaging students in a discussion about the pros and cons of particular approaches, they understand that we have made a considered decision and so, even if our decision is not the one they wished for, they understand it more and therefore are less likely to feel that we are ignoring them.

Mostly we believe that these points enhance the students' overall educational experience. Should staff need a further encouragement, we would also argue that these have a positive benefit on what students say about us in, for example, the NSS.

By way of support for our argument, we would like to end with a quote from a student at a university whose NSS scores were excellent. Having reviewed the teaching provision in these universities, we consider it implausible that the detail of what this university provides is genuinely better in almost every category covered by the survey. Rather we think that good NSS results can be – at least in part – explained by the students' sense of belonging, their belief that they and their views are valued, their loyalty to staff whom they see almost as colleagues, and an understanding of the reasons why things are the way they are. The following quote, from a student at the university concerned, illustrates the point:

> *"The teaching style on the course has helped my confidence, the tutors treat the students as equals, I have never been talked down to at [university]. I feel that the tutors and students work as a team aiming for one goal and that is the students' understanding and enjoyment of the subject."*

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3.3 *Student experiences of the transition to university*

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Introduction

University is the best time in your life, time to spread you wings and find your true potential. Friends you meet at university will last a lifetime. Is this the reality of university life for some or all of our students? How do students settle into university life, adjust to the unfamiliar and learn to cope with the range, pace and style of university mathematics?

We look here at student views of their experience of starting university in our partner institutions in the More Maths Grads project and in our own institution. We also report some views expressed by colleagues about how students cope during their first year. All the quotes are from interviews conducted at our own and partner institutions. It is worth remembering that mathematics students have the same general experiences on moving to university as all other students, and it is in this context that they are initially coping with university mathematics. The first section looks at this settling in process as experienced by mathematics students.

Settling in

In the sample of students from partner institutions who responded to our questionnaire, over 30% rated as important that they lived close enough to home to visit at weekends. For these students homesickness may not be too much of an issue. For those from further afield it can be different:

> *"I found that I'm really close to my mum, so I did miss her loads right at the beginning."*

> *"it was hard as well to like… you were just moving to somewhere new as well and you had to do your work as well… I can't cook… I didn't know how to wash my clothes… I had to learn…"*

> *"Well the first weeks I moved in… I'm from seventy miles south of here, so was moving in on my own. At first it's quite scary, 'cos new area, new people, new lifestyle, it's quite a change";*

and even more so for international students:

> *"To get in and adapt in and doing things it is totally different you know."*

Even after initially settling in homesickness can strike again unexpectedly:

> *"And then I was really fine and then like about, well can say, about three weeks ago was just like 'I want to go home. I don't want to be at university."*

Usually though students get through this, make friends and start to enjoy life.

> *"Then after you get settled in, you meet up with new people, it's good."*

> *"It's great. I love it."*

> *"social side… brilliant"*

This process can be helped by what happens in the first weeks of the course:

> *"On the first week, we were put into our tutor groups and we did things together in our tutor groups. And that is how I met most of my friends."*

Among the tribulations of moving away from home is managing money for the first time. Some learn by experience:

> *"Spent far too much money in the first four weeks, then you have to live on rice for the next..."*

Others seem more careful from the start and temper their desire to have a good social life with prudence:

> *"I mean I've ot been one to go out and get drunk every night for weeks on end, because I'm quite, I try to be quite good with my money. But we've had house parties and stuff like that. So we've still had the opportunity to do stuff."*

As the quotes included here testify, the start of university life can often be an exciting and enjoyable time. It may be though that the students who participated in the interviews were not completely typical. One group described themselves as "the loud ones that get told off". In the personal experience of most colleagues will also be examples of students whose pervading sense of loss of the familiar on leaving home has strengthened rather than decayed over time.

Expectations and Reality

Open days, prospectuses, teachers, friends, family and the media have all helped form a picture of what to expect walking into the campus for the first time. It is difficult to go back into our own shoes at a time when university life and the contents of a university course were the cause of both apprehension and misapprehension. What range of experiences and mathematical content do our students expect, and how accurate is this expectation?

Whatever their previous experience, all students face new mathematical techniques, and also mathematics of an unfamiliar type. It comes as a surprise that mathematics is so diverse - and divided up into so many separate parts. Students are used to the A-level divisions of pure and applied. Arriving at university they find pure is something completely new, what was previously referred to as pure has become methods, and applications are far wider and may not include mechanics:

> *"The reality of what maths is like post A-level is a bit of a surprise"*
>
> *"There is much more to it, and it is better than A-level."*
>
> *"...the course is really different; there was a lot of application. I was just expecting it to be just general maths to begin with, and then go on to application. I think it's good, but I think it's quite a big jump. And I think, I don't know about everyone else, but I certainly wasn't expecting it. And I found it bizarre"*
>
> *"I think application's quite a bit more different than just maths itself; maths itself is fine."*
>
> *"I didn't expect maths to be as wide as it is… I thought it was all centred around the mathematical methods type stuff, but the, the problem solving, I really like problem solving, that's probably my favourite one."*
>
> *"I didn't do further maths so like complex numbers, that's all new. At first I did find it a bit hard."*
>
> *"…it was really different... more computers than I was expecting. I expected it to be a bit more like pure maths".*

The majority of students we talked to did find university maths very different, as exemplified above. Opinions differ about which are the good bits and which cause more problems. Some had found a big change in level and had been surprised by the amount of computing and application. Others had clearly welcomed the challenge of new areas such as "problem solving". Students were not completely unanimous however in how new they found things:

> *"I did further maths A-level so a lot of work for me has just been going over that maybe in a bit more depth,… I know it's to get everyone to the same level then."*

This last quote might say something about the level of prior knowledge that this course expects - namely that there is no expectation that students will have taken Further Maths. It might also say something about the stage of the course (end of the first term) or the student, or some combination of these.

It is interesting to see evidence of student's preconceptions coming out in some of their general responses about expectations at university. Clearly some hadn't thought that mathematicians could be much more extrovert than, as the old joke has it, "looking at the other person's shoes" when talking to them.

> *"The social side of maths really isn't like you'd expect."*
>
> *"I didn't expect to meet so many lively people on a mathematics [course]."*
>
> *"Went out with the lecturers and you expect to kind of like meet, I didn't expect I'd meet anyone who's quite as lively as I was."*

Perhaps in hindsight the interview should have pursued further exactly what sort of person the last student did expect to meet! Thinking more generally about expectations of university life, there was a variety of opinion about how much university accorded with expectations from the positive:

> *"School was easier… but this is more interesting and better because it forces you to teach yourself";*
>
> *"It's fairly what I expected. Enjoying it though...";*
>
> *"Its pretty much fulfilled my expectations with the exception..... I would have chosen one different module";*

through the practical:

> *"I like having Tuesday afternoons off"*;

to the neutral:

> *"…different in lots of ways, it's hard to try and remember what I was expecting it to be like"*;
>
> *"Been about what I expected I think. But I did the foundation year so… I had a different point of view I think";*

and the negative:

> *"It's been a bit of a roller coaster";*
>
> *"I think [it would have been] more enjoyable if it had been more what I was expecting. I think I was a bit shocked by the difference";*

"I think I was somehow expecting it to turn out the way I was expecting, and it didn't. And I found it a bit difficult to adjust to."

The reactions to starting university highlight the non-uniformity of the student group and the variety of perceptions about the mathematics they encounter and the more general process of adjustment to university life. It is also evident that in general on arrival they have a very hazy picture of what university maths might be like. This shows up the need for the outreach work that is currently in progress by both the More Maths Grads project and other groups. It also possibly illustrates a need for a better explanation of university mathematics in layman's terms for those considering embarking on it.

Coping with University Mathematics

The journey through the first year of university mathematics is, like a game of snakes and ladders, beset with pitfalls and moments of triumph. There is a wide range of students, from the able and confident:

"...there are some parts which I find it very easy and .. I can pick up the concepts very quickly And then other things which I find hard and challenging, I enjoy both aspects of that equally"

to the opposite end of the spectrum:

"I came in with nothing really. I failed my exams at A-level, everything. Came in just on the off chance I might actually get somewhere."

This means that the journey is perceived in many different ways. How it is perceived may not depend on the absolute ability of a student, but their ability relative to their peers. Someone with an A in Mathematics at an institution where the expectation is that students will have taken Further Mathematics may feel less confident than someone with a B in Mathematics at an institution where many students have come with a C:

"I've not done Further Maths .....I was like what's that and they said 'oh didn't you do that in Further Maths?'"

While most students do eventually find their way through the first year with varying degrees of success, some have genuinely made the wrong choice or perhaps the right choice at the wrong time. As colleagues pointed out, it may be better to help them face this in a constructive way at this stage rather than to continually struggle throughout the course.

One difficulty to be overcome, a major one for some students, is the change in teaching methods and group size.

"I found it you know, strange to be in such big classes of people, because you know, last year I was in a Further Maths class of me and another girl."

"The first term it was weird not having the teacher's personal attention... being lectured to without having to do the work in the class."

"I just felt really stupid, asking for help in front of everyone."

"Hour long lectures without being able to test your understanding are difficult - much more down to a student to go and seek help."

"[At] A-level you sort of do get pages and pages of examples."

Students need to acquire a new way of working to cope with a continuous lecture for an hour without a break to try out a technique. The large group size also means that a student is reluctant to ask a question either because they don't want to interrupt the lecturer or because they feel intimidated by the presence of all the other students. The pace of study also presents a problem as the focus moves on to new areas when at school there would have been class time for attempting a large number of repeated examples of a particular technique. A new way of working requires greater self-discipline to keep up to date with the rate at which work accumulates:

"It's really easy to not do stuff, because you haven't aligned yourself. And if you're not the kind of person who's easily motivated, it's really difficult."

"It needs a lot of discipline and it's totally different. Sometimes you feel like when you're taking your notes you know you ask yourself is this for example what I expected and somehow you have to make adjustments within yourself if you realise things are not going your way."

"I feel I've a bit better idea of how to do, how to manage my own time and stuff now. But I think it's just really, really easy to let it slip kind of thing."

"I didn't realise quite how much work you had to do. And to be honest, I was quite lazy first term."

These students have clearly given some thought to their progress and their method of working. At one institution an on-line learning log is used to facilitate reflection, of which a colleague said:

"Reflection is really important because without that they, they're not seeing their advance along the path, all they're seeing is where they are now, and they don't realise that they're actually developing."

Students generally do not bend under the weight of adjusting to their new situation, but instead are inventive in finding strategies to cope. A variety of snippets of friendly advice for new students emerged from students and colleagues.

- *"Enjoy it - don't be afraid to be a geek."*
- Be part of a social group:
  "there's so many social groups and within every social group there's always someone (who says) "I'm stuck on a question", someone within my social group will help me."
  "those who are not part of the right social circle where that reassurance is, are at risk of dropping out."
- Try to keep up:
  "At uni no one prompts you to do stuff, you just have to do it, that's the hardest."
- At least try and get to Christmas - as one colleague said:
  "If they can survive and get to Christmas in one piece - do all the assignments, even if not particularly well - then most of them will be OK."
- Don't despair if things haven't gone smoothly at first. The student above who was bemoaning their laziness in the first term managed to rectify that later *"Second term I've had to work a lot harder to practically catch up."*
- Be careful to explain what you are doing when writing up your mathematics. As another colleague put it:
  "You can always recognise those students who make an effort to explain what they are doing... they'll do well, they always do."
- Don't worry too much if you don't understand everything immediately:
  "as long as everybody doesn't understand, that's okay and we'd speak to people in the years above and they'd be like, "Oh it's okay, it all comes together in third term.""

This raises the question as to how such advice could best be distilled and effectively passed on new students.

Among the many encouraging things we heard about students' progress was the simple statement from a colleague "they certainly get better at it" and the experience reported to us by another colleague of a student who was pleasantly surprised to discover that they actually quite liked mathematics, because they'd only done it at university as the "least bad of all the options".

Ideas

Generally students are surprised by both the teaching methods at university and the nature of university mathematics. They gain confidence as they learn more about the range of things that they are studying and find a successful method of working. They gain support from forming social groups and from hearing the experiences of later years of their course. Things which can be put in place to help these processes along can help students to settle in more quickly and generally have a better experience and these include:

- a guide available to A-level students and other prospective students about the diverse and applicable nature of university mathematics in "plain English";
- opportunities for students to hear about typical first year experiences and how difficulties have been overcome. This may be through a booklet and/ or through organised contact with students in later years of their course. While it is probably useful to have something on this in induction week, it's inclusion could also be valuable as they proceed a little further into their course, perhaps in study skills sessions;
- support for forming social groups - as noted in [1];
- a mechanism for students to reflect on how things are going through a paper or on-line learning log (see further discussion in [2]).

References

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3.4 *Staff views of students*

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1 Introduction

Over the last few years, there has been much discussion amongst higher education mathematics professionals about what has been termed the 'Mathematics Problem', namely students' preparedness – or lack of it – for undergraduate study. A levels, it has been argued, no longer provided an adequate preparation for mathematical study at university, and widening participation and a (now hopefully reversed) decline in mathematical applicants has forced universities to accept students with lower entry requirements than might once have been the case. For example, in Measuring the Mathematics Problem [1], Hawkes and Savage reported an

> *"increasing inhomogeneity in the mathematical attainments and knowledge of students."*

Furthermore, they point to a

> *"steady decline over the past decade [1990-2000] of fluency in basic mathematics skills and of the level of mathematical preparation of students."*

The latter assertion is based on a variety of evidence particularly from diagnostic tests over a number of years, for example reported in [2].

We might add that there has been much debate about A level standards in the mainstream media too, with many people believing there to have been a drop in standards despite steadily increasing numbers of students attaining the highest grades [3].

In addition to discussion about students' mathematical abilities, questions are sometimes raised about their key study skills and motivation for study. It could be argued that increased participation in higher education could draw into universities students with lower overall aptitude for academic work, or that as the proportion of school-leavers going onto university has increased, those with little direction are more likely to follow the same route out of expectations rather than academic ambition.

As part of our research for the More Maths Grads project, we interviewed staff from four different universities and, unsurprisingly, there was no shortage of examples of how students fall short of our ideal. In a previous article [4], we discussed the students' perceptions of their first year studying mathematics and the transition from school to university. In this article, we present some of the staff views on the student body, in particular their preparedness on arrival at university, and pose some questions about the implications of these views on the student experience.

2 Is there something wrong with our students?

Let us start by considering the range of shortcomings – whether of the A level system, school education or students themselves – which were raised by staff. To try to answer this question we present a sample of what they said which we have grouped into three broad categories:

- mathematical ability on entry;
- motivation;
- key/study skills.

Here we focus only on the problems which staff identified; whether these views are universal, and the extent to which they apply to all students is considered later in section 4.

2.1 Mathematical ability on entry

Perhaps the most common criticism of students, or of the A level system, relates to the level of students' mathematical abilities when they arrive. We use the word 'ability' somewhat loosely to start with and consider later more precisely what is meant by this.

Firstly, a number of the staff we interviewed spoke about students lacking competence in what they viewed as basic skills, such as algebraic manipulation or integration.

> *"They don't understand fractions, so when it comes to algebraic manipulation, it's not second nature and you can see them struggling."*

"[Some] groups they seem to struggle at a much more fundamental level [in] that they're not being able to integrate […] 1/x2 and that sort of thing, so other groups struggle on a […] much more fundamental level[…] I was quite surprised at that."

Alongside a criticism of students' basic techniques came comments about their ability to communicate mathematics properly:

"one of my big things is getting the students to write their Mathematics properly. It's no good just bunging down a load of unconnected statements…"

and a particular mention for the way some students misuse mathematical notation which we believe ought to be second nature:

"what really annoys me is that students don't use mathematical language and they use equals signs with gay abandon."

Perhaps even more common than criticism of students' grasp of techniques was the view that students' approach to mathematics was algorithmic rather than based on sound understanding. This was linked for some to their algebraic manipulation skills:

"you get the occasional person muttering 'change the side, change the sign' under their breath as you are going through it. It's not what you want to hear from somebody who has done an A level in Maths. They should be thinking add –x to both sides."

More widely, students were thought to have a 'recipe' approach to solving problems and this was viewed as being symptomatic of the approach taken in school and at A level.

"Most schools seem to provide… a fairly instrumentalist algorithmic approach to almost everything."

"They don't know how to cope with problems that they don't know how to do. In A level, almost always when you see a problem…you know how to it."

Staff sometimes felt that even where students could 'get the right answer' they did so in a way that revealed a lack of mathematical thinking

"I mean even something as basic as solving a quadratic equation, people forget what they're doing, they just know this formula that they've remembered since they were sixteen."

"If you differentiate this then you have this, and so on. And they know what the answers are but they don't know where it's come from."

According to some staff, students sometimes had a clear view that staff ought to teach in a way which enabled them to continue with this approach.

"I always get these students who seem to think that, '[…] if you don't give us the right examples and so that we can do the exercises, then you're not doing your job right,' that's how some of them view it."

"I had students years ago saying, 'You're not a very good teacher' and I said, 'oh why?' You know, they said, 'because your examples…' What it boiled down to: 'I can't just mimic the examples to do the course work'."

The pattern-spotting approach was reported to extend beyond spotting the nature of the problem from the actual mathematics required, but also into a supposed code in the language we use.

"I remember a bright student once came to me and he complained and he said 'You shouldn't have used that particular word in that question.' And I said 'Why on earth not?' and he said 'Well we were taught at school, every question has a key word in it and that key word alerts you to what method you have to use. And you used that key word so I knew I had to use this method. And I got the question wrong.' And I had to explain to a bright student that you're actually supposed to read the question. And he was astonished."

A common theme of this discussion was that staff viewed student algorithmic approaches to have been ingrained particularly through preparation for A level. One talked about

"this methodical way that's been hammered into them since sixteen,"

whilst another said

"A level mentality… is preparing for exams, learning methods, when you see this sort of question this is the way you should answer it and train, train, train…"

We note that staff were not critical of school mathematics teachers themselves. As [1] says,

"compared to their predecessors, they have to deliver a different curriculum, under very different and difficult circumstances, to quite different cohorts of students."

Rather staff seemed to view the failings as related to the nature of the A level

"my feeling from the students I get […] is that A Level Maths is mainly just techniques without understanding,"

and the pressures on teachers and schools by the monitoring of exam results:

"my personal opinion is that it's a fall out from having league tables. That schools, all schools need to do now is get people through exams, and that's not the same as teaching them."

Whilst the preceding comments relate primarily to the attitudes developed during A level study, there was also some discussion about the actual content of the syllabus. A number of staff mentioned in particular the lack of proof in A level.

"When they get here sort of the first time they've ever met a proof, they have no idea what, what's expected. The proof just looks like a big scary word."

"It would be nice if there were something in the way with proofs […] Having seen the idea of a proof before they came here, I think it would make our job easier, so something like say $\sqrt{2}$ being irrational. I think that one should be coverable at a school level."

Some staff acknowledged being somewhat ignorant about the actual content of A levels:

"now I'm not an expert on the A Level syllabuses…"

"it's a long time since I've done 'A' Stats, and I'm not fully up to speed on exactly how it's changed,"

"I thought that was at school level, I thought they did [this topic] at school. I mean I've only got old A level text books […] don't know if they still do."

Some of those who did know the supposed content said that this was not reflected in student knowledge or skills.

"Our experience is that you can look at the syllabuses and the text books all you like, but what they seem to know when they arrive isn't very well reflective of what the text book seem to indicate they've been doing to pass the A-level and the grade they've got. You know we get people with As and Bs who seem to be fairly clueless about quite a lot of maths that you would take for granted."

"It is a continual surprise when people coming into higher education with good A levels and apparently very patchy subject knowledge. We tend to blame the modular system – you've got to have something to blame. We've sort of learned that – don't need it again."

The net effect of all this might include some shock amongst our students:

"I think that for most of them, and I'm sure this is the case almost everywhere, that the reality of what maths is like post A-levels is a bit of a surprise."

In this section, then, we have reported what staff said about their incoming students' abilities. In fact, when we say 'ability' this covers five broad areas, namely

- mathematical techniques – whether students are competent at algebraic manipulation or integration, for example;
- mathematical communication – how they write down their mathematics;
- mathematical knowledge – whether they have met the topics we want them to have met;
- mathematical attitudes – for example their approach to problem solving, their ability to construct a watertight argument;
- mathematical understanding – do they understand what they are doing even if they can get the right answer?

(Of course, there are intimate connections between these five areas. For example a lack of understanding can lead to an algorithmic approach to problem solving; an inability to communicate mathematics effectively can be symptomatic of a lack of appreciation of the place of rigour and contributes to problems in constructing arguments.)

In all five areas, staff were often critical of the level of preparedness for undergraduate study.

2.2 Student motivation

Are our students as motivated and enthusiastic as we would wish? Let us start by recognising a distinction between these two attributes:

"you said motivated, I mean that's different to being enthusiastic, I mean they're two different, two different things.[…] When I talk about enthusiastic, enthusiastic students tend to be quite motivated just by their enthusiasm but [there are] ones who are motivated by: "will I get any marks for this?"

This latter view, that some students are motivated only by what gets them marks, is one that is expressed by a number of lecturers. Again, pre-university experience is sometimes thought to be the problem.

"By the time people have come to us from school, they already have it absolutely ingrained in them that coursework is for marks. They don't get a mark, they don't do it. Okay, this is terrible. But if we don't mark coursework we know they wouldn't do it and so they wouldn't learn."

"You try to get across that the best way to succeed in maths is to be interested. You should be wanting to learn it, you shouldn't be thinking of it as a chore. But I don't think many students really see it that way. They've been brought up with an exam culture of course at school, it's very test test test test."

Many colleagues will recognise the reasons why one person said

"I tell my students that they're allowed to ask questions except […] they're not allowed to ask, 'Will it be on the exam?'."

Of course, engagement driven by marks is probably a symptom of a greater motivation, namely the desire for a good degree at the end of it. Many staff reported that

"getting their 2:1 degree so that they can go away and get a job"

was the main driver to students presence on the course, rather than any love of the subject. They are here because they believe that

"with a mathematics degree they can find decent job with a decent salary."

At one of the universities in this study, which offers a variety of courses which combine mathematics with business or finance, enthusiasm for studying mathematics amongst combined honours students was particularly questioned.

"I'm reasonably sure they are not really interested in the subject. Of course they engage with the subject, but they [would] study business or economics if they [had] been admitted in their department. I think they are ending up here because we take them, we treat them reasonably well. And they have the impression with a mathematics degree they can make their lives somewhere."

This view was not restricted to that university, however. At another, one lecturer said

"I think there is a large, a disturbingly large proportion of students who come and study maths and they don't really like it, they'll do it, they'll do maths at university cos it's their least worst subject, yes, it's not necessarily their best but their least worst."

Thus we might summarise these comments relating to problems with student motivation as: their being insufficiently committed to the subject (perhaps not even liking it), being motivated during their study by those things – ie assessment – that contribute to their gaining a good degree, so that they can achieve their main incentive, namely getting a good job at the end. Whether this view is accurate and what students say about their own motivation and aspirations is discussed more fully in [5].

2.3 Key skills/study skills

Students' ability to cope with undergraduate study is not, of course, only about their explicitly mathematical ability. To this we must add what we might term key skills or study skills.

Whether their motivation is one of enthusiasm for the subject, a yearning for good marks, or the longer term incentive of a good degree and a good job, we might believe that a rational approach – and a key study skill - would be to get the best value for money from your course by attending every class possible. Many colleagues reported that this was not what all students did!

"In the first few weeks, eighty to ninety percent of our students show up […] Then the number normally drops to something between fifty and seventy percent. […] And after […]week seven, the number goes normally down to something between thirty and fifty percent."

"[The classes have] theoretically 35 students. […] There's still exercise classes that pull 20 people and there was one today where only 2 people showed up, so … We tried actually to even out numbers, to make it compulsory but there's only so much you can do."

Some staff questioned the student approach to learning in other respects too:

"I was looking at marks earlier today and there are people who are getting consistently over eighty and there are people who are getting consistently under fifty. I don't know how much is ability and how much is study habits […] One thing we talk about a lot is the fact that they don't seem to know how to learn."

We have already discussed in section 2.2 a perceived lack of motivation for learning the subject itself in favour of a strategic approach to crossing the next hurdle. Some staff reported this in terms of students failing to understand the material properly, and not appreciating that this was going to cause them problems later on:

"they feel like their first year doesn't count, well it doesn't count [towards degree classification…] and so like one of mine failed one of his courses and I was like, 'You know, this doesn't really reflect what you're capable of.' […] and he just, he was like, 'Oh it doesn't matter, you're allowed to fail twenty credits'."

Another reported how students were not interested in understanding the subject fully:

"at university level you've really got to understand what you've done, not just going through the motions. And a lot of them have a real trouble with that, the whole concept of understanding something seems to be.... I mean, […] I'm not

even sure that they fully understand what I mean by it because it's just not something they're taught at school […] I mean when I talk about understanding they seem to think understanding's being able to do it."

There was also a sense at times of students being unwilling to engage with working hard to understand mathematics, again sometimes related to their previous experience or expectations:

" you shouldn't [do a maths degree because you think it'll be easy], but I think some people do in terms of, 'Oh I've found maths easy at school but I'll probably still find it easy at uni' and the amount of people who that is actually true but it's so small, like really small."

Some staff also questioned whether students' abilities in other key skills – notably written English – were adequate. One talked about being unable to

"assume that students who came to university could write a complete sentence…with a capital letter at the beginning and a period at the end."

This echoes frequently made criticisms of graduate's poor basic skills, for example [6]. On this topic, we note the comment of a colleague that although he felt able to write good English, he did not have the skills – or the time – to teach students how to do this. When and how, we might wonder, can a mathematics student pick up key skills which they haven't successfully learnt at school?

"I mean, I think it's sort of sad that we have to make up for all the educations in society's ills. We are not allowed to drop standards of course but we have to…"

In this section we have considered what staff said about the shortcomings of our students, that is to say, the skills, knowledge or attitudes they lack relative to what we might believe they should have. Next we consider their relative standards; that is how they compare to each other and to previous cohorts.

3 Are standards declining?

We have already seen that many staff have – at the very least – reservations about the style and standard of mathematics taught at A level. Many of their comments suggest that staff have an idea of what a student ought to be like. Were they ever as we should like? Have the problems become worse? A decline in standards is what is discussed commonly both amongst professionals [2] and lay people [3]. Some staff in our study saw this as almost axiomatic:

"given the general fall in A-level qualifications…"

even if it is immediately qualified

"…er, or we perceive as being lower and lower standards."

Comparisons were made over a variety of timescales. Some talked about 'over the last 20 years' and one about how the standard had

"certainly changed since I was at school."

Nor was it just the standard of mathematics which was thought to have changed. The quote given previously about students' failure to write good English actually started

"I mean, in the old days you could assume that students who came to university could write…"

Student willingness - or ability - to work hard was compared unfavourably to the past:

"I think students used to work more between classes than they do now. Whether that's because students are working to bring in money, which in some cases it is, or what, I'm not really sure."

Similarly, their motivation for studying maths at all is sometimes questioned:

"When I was a student, students chose mathematics or physics because they were good at it. Maths here is not anything you choose because you're good at it. It's a negative choice. You're doing it because you're least bad at it in high school. You're doing it because you can't get into business school."

To this discussion we should add one contrary view, from a universities where other staff talk about declining standards.

Q: "Have you noticed any kind of change in the standard of first years coming in?"

A: "Not in very recent years. I mean I, no, our sense is that they are […] actually better this year than they were last year and slightly better last year than they were before, […] I think they are getting slightly better. But of course, I mean we're using all their A-level grades, and so we're not necessarily saying that they know more mathematics, but you know, it's always this very complicated mix ability and commitment to spending time doing academic work but one way or another there are slightly fewer unsatisfactory students than there were a year or two ago, but it's only very marginal."

Whilst this lecturer was talking about improving standards we note the suggestion that this was only in the last couple of years, and would add that entry requirements have slightly increased at this university.

4 Are they really all that bad?

In sections 2 and 3, we have presented staff views about students which we might summarise crudely as: they have weak mathematical ability in a range of areas including having significant gaps in their knowledge, poor mathematical attitudes, and incompetence at standard techniques; they are motivated by gaining a qualification (and hence by marks) but unenthusiastic about the subject; they have poor study skills; and things are (mostly) going downhill. Is that an accurate picture - either of our students, or our view of them?

In fact, our opinion of students is much more mixed than this description might appear at first. At the start of section 2 we trailed the fact that we have presented up to now the difficulties which were identified by staff in this study. Let us now attempt to make the picture more rounded.

Firstly, we should state explicitly that many of the comments quoted already were in response to interview questions about whether staff perceived problems with the student intake, either in terms of their ability to undertake undergraduate study or a decline in standards over the years.

Secondly, at one point or another many staff acknowledged the differences between students, whether in terms of their abilities or their motivation and enthusiasm. The following quotes give a flavour of this:

> *"[This tutorial group of] students are really engaged […] and one of them in particular is […] questioning everything. And that's great, I think they should be actually, I think if more of them… […] It's quite an extraordinary group."*

> *"I've got some very good students, I mean, some of them are lots of fun. And you know, good to teach, good to interact with, but some, you know, if you still have trouble adding fractions…"*

> *"I think some of them are definitely here 'cause they love, love mathematics…"*

> *"There is a good culture here of students, I mean like this semester I now got to have almost 100% attendance record from the students. Particularly… Well that's a good group…"*

> *"Yeah, we have some pretty good students, yeah, some of, the best of our students are pretty good, yeah."*

Similarly, staff recognised that perceived problems with A level were often dependent on the opportunities students had had before arriving.

> *"I get the feeling from A Level, there's a mixture of experience that they've had of calculus, some of them have been given some of the rigorous background to it, and some of them have been just given a set of rules."*

As reported earlier, Hawkes and Savage [1] found an 'increased inhomegeneity' in the students' attainments. Similarly it is possible that the views expressed in sections 2 and 3 about student shortcomings and a decline in standards are not a reflection of changes in the standard of the best students, but rather that the we now have a wider range of students on our courses than in the past. In effect, perhaps our classes are more mixed (in terms of abilities and attitudes) than they once were.

Whilst it is worth reminding ourselves of a truth which may be lost in a discussion of mixed ability teaching – namely that any class with more than one student is a mixed ability class – it could be argued that in the past, when a much smaller proportion of 18 year olds went to university, those that did were likely to be both able, and committed to academic work. With increased participation, perhaps the range of aptitudes and attitudes might have increased.

Certainly some staff talked about the problems they saw as caused by the diversity of students on the course.

> *"We've got very good students here as well, we have a very skewed distribution, a very, a very large tail of weak students. Enormous amount of effort going into getting those people just through the system."*

That sense that weaker students absorb a disproportionate amount of energy was reflected elsewhere as well, with an implication that the better students were sometimes neglected as a result

> *"I think we should do a better job for them, that's [...] We're always so busy bending over backwards and dealing with the difficult cases and so on that it's, it's not always easy to, to stimulate the best students enough."*

At one university in particular, where students can typically gain entry with a C in mathematics at A level, it was suggested that higher entry requirements would be part of the solution to mixed abilities.

> *"In an ideal world, I would rather have fewer students with higher entry requirements and do a much much better job for those."*

> *"It's not really a problem of numbers, it's a problem of quality. We would like [our] students to be somewhat better quality than they actually are."*

One might expect that, if this approach were effective, the university with the highest entry requirements would have fewer complaints about mixed abilities on their course, but this was not evident. The following extract is taken from an interview with a staff member at a university which requires 3 As at A level.

Lecturer:"I mean our problem is we [have a] range of ability of our students, I think, or the rate of success on the course is very, enormously variable, and we have the feeling that our best students are actually not being stretched enough and certainly some of them do complain a bit in the first year [...] that there's not enough new material, but at the bottom end there are certainly some students who find the course too abstract, too difficult, and are not enjoying it. And some of them struggle on. And it's accommodating ourselves to that wide range that's difficult. [...] "

Interviewer:"It's quite interesting that you talk about a wide range of students when almost all of your students have an A in A-level maths."

Lecturer: "Yes but in a normal distribution, the top 10% there's more variability, you know, so actually, the more .you push up towards the top end the more variability there's going to be..."

Of course, the latter comment assumes that universities with lower entry requirements don't attract any exceptionally good students (some do), but the key point is that raising entry requirements is no guarantee that staff concerns about mixed abilities will be eliminated.

In a similar way, some staff felt that their weaker students would have been better off studying elsewhere. The lecturer we just quoted also said:

"I think for some, some students would be better off at a university where the pace wasn't so great and there was more focus on teaching. But we understand the reasons why students decide not. It's a difficult issue. Unfortunately, students are very conscious, some of them are quite conscious of prestige of universities."

The subject of how students choose their university is discussed in more depth in [7].

Another theme which emerged from discussion of mixed abilities and attitudes concerned what we should do about weaker students. One member of staff, subject to the caveat that

"the rules will always be generous to the student and probably rightly so in the sense of [...] allowing resits and any half-baked medical excuse will do and that sort of thing,"

said that given a free hand to change any aspect of the course, he would

"be harder on the students."

Interviewer: "In what kind of way?"

Lecturer: "If, if they don't do very well in the exams then they're out, if they don't turn up for tutorials then they're out."

His was not a solitary voice. At another university one lecturer said:

"You know I'd love to be in a system where we could honestly tell the students [in the] first lecture: '[by] the end of the year, half of you will be gone'. And I don't mind teaching 1000 students if I have that threat dangling over their heads."

Whilst these quotes sound relatively hard on students, there was also a sense from some staff that allowing students to continue into the second year after a poor performance in the first was not to their benefit:

"[Of the students who trail credits] about roughly 1/3 graduate with 2ii degrees, 1/6 with 3rd class degree, and half don't make it. So their chances of graduating are quite small"

"There are a few who you think, well, you're never going to really succeed."

Of course, reconciling these opinions with a desire to maximise income from fees is not easy.

One aspect of mixed abilities which we should mention briefly is the question of whether students have studied Further Mathematics at A level. A number of staff expressed an opinion that many of the problems they identified with Mathematics A level were significantly reduced amongst students with Further Maths.

"I've noticed a big difference between those who have taken Maths and that only and those who have taken Maths and Further Maths.[...] Massive difference because in Further Maths I think they see real mathematics."

The question of the benefits of Further Maths is complicated for university departments of course; unless every student is required to have taken it, having some students with it simply extends the range of mathematical abilities on the course.

5 Coping with the transition

As we said earlier, there has been much discussion about the difficulties of transition to university mathematics, and correspondingly there has been substantial effort in most university departments to ease this process. Insofar as most of our students successfully gain a mathematics degree, clearly the majority do succeed in making this transition. For a discussion of how straightforward or difficult students find this, see [4] and [8] for example. Let us here just briefly consider some differing staff opinions. For a start, staff recognise that this can be an unsettled time for students, both personally:

> *"you're not dealing with people who are settled, adult individuals. You're dealing with people who are eighteen and so they're not kids but there's a lot of [...] changes happening"*

and in terms of their involvement with mathematics:

> *"I think that for most of them, and I'm sure this is the case almost everywhere, that the reality of what maths is like post A-levels is a bit of a surprise."*

Do students find it difficult to adjust to a new style of mathematics?

> *"I think they do, but I think they cope with it rather well once they do [...]The higher level of abstraction and doing things that they... and I think that helps them quite a lot. They do seem to pretty much get the hang of it at the least at the basic level quite well."*

> *"We've certainly had quite a lot of students who just go 'Goodness me there is much more to it and it is better than A level'."*

On the other hand

> *"other staff think, this goes back to more maths grads as well, by the time we get them it's too late for lots of them. We work very hard. We work very hard to make them…You have to have something hardwired in your brain, otherwise you can't progress because even in their third year we still have students who worry about where do I put the brackets when I multiply, and if you have those people still in the thirdyear it's a waste of time for everybody, and if they don't have it when they get here and they're not picking up when they get here, it's too late, simply too late."*

Whilst this lecturer starts this statement saying 'other staff think' by the end of it we might conclude that this is an opinion he also shares!

6 Some reflections on the university mathematician

6.1 Lecturers' prior experiences

Before we go any further, allow us to present a caricature of a typical mathematics lecturer. Whilst this is necessarily a broad-brush description, we anticipate that most readers will see some reflection of themselves and their colleagues here.

We probably enjoyed mathematics from an early age; indeed we were probably fascinated by at least some aspects of it. What is more, this enjoyment was coupled with ability, whether we believe this to be innate or learned. Being above a certain age, we most likely did the old GCE O level rather than GCSE, and any problems we might attribute to the current A level occurred since we took it (regardless of age, most people consider any deterioration in standards to have occurred after they achieved the qualification!). We may have taken Additional Maths O level and Further Maths A level and most likely combined the latter with Physics, giving us an added opportunity to use mathematics.

We probably quite enjoyed school; worked hard and achieved strong results at least in mathematics and science, if not in all subjects. Our motivation and work ethic must have continued – at least to some degree – through our university education. What is more, at school and university, we coped, if not thrived, in examinations.

Our school mathematics teachers were likely to have been specialist mathematicians, and prior to the obsession with league tables, might have had the freedom to teach maths without a constant eye on the next set of public examinations. Even if we did not have universally excellent teachers, clearly overall the teaching at school and university must have suited us sufficiently well so that we obtained good results – had this not been the case at any point we should have been thwarted at the next stage of our career (or been discouraged from pursuing it). Instead we progressed through the various stages, successfully negotiating the change to different styles of working at university and gaining a good undergraduate degree classification; maybe completing a master's course; probably completing a doctorate with the associated dedication and independent work; and we most likely spent a period as a post-doctoral researcher, before becoming a lecturer.

In short, in order to arrive in our present employment, we have not only benefited from interest in the subject, ability, educational opportunity, motivation, work ethic, ability to cope with examinations, adaptability, and independence; but in addition we have done so to a degree far beyond the majority of the population. We are, to put it bluntly, rather strange.

However, we are not always aware of how strange we are. Relatively few of us have been employed outside of education, almost certainly not for extended periods. Using mathematics has been central to our working life from the day we started A level study and, particularly as our careers have progressed, we have increasingly been surrounded by people whose experience is broadly similar. Our skills, attitudes and peculiar characteristics have become the norm to us, both because of our own life history, and by continual exposure to the tiny minority of other people who share them. We have perhaps forgotten that we were not typical children even in our day (we liked and understood maths); we were not typical undergraduates even compared with our fellow students (we worked hard, achieved good degrees and went on to further study); we were not typical postgraduates compared to our peers (we went on to become lecturers).

The reader may dispute the preceding discussion at least to some degree, and you will know (better than we ever can) the ways in which this is not entirely true in relation to your own life. However, we would invite you to consider for a moment – realistically – how much of this is true for yourself or your colleagues? When we consider our opinions of our students, it is important to realise that our perception is inevitably bent through the prism of our own rather unusual experiences.

6.2 Lecturers' motivations and enthusiasms

We could go further and speculate about why staff have pursued a career as lecturers. Here we might be on shaky ground to generalise too much – staff motivations for their career are of course varied – but, perhaps particularly in research-intensive universities, many staff are primarily enthused by the opportunities to pursue their research. When we asked one lecturer with significant teaching responsibility to tell us the best thing about his department's maths course, he volunteered instead that he considered the worst aspect was

> *"it is a research intensive department, so staff have only got a limited, they don't focus, they don't regard, I mean, I said,… they take their teaching very seriously, but it's not for most staff the main focus."*

At another (also research intensive) university, one member of staff said

> "[Previously] my motivation for teaching was I offer special courses, I do a really good job, and I attract students who do a […] PhD. Here […] there's so few people going on and even being qualified to go on. […] Undergraduate teaching pays the rent. You do it well because you have more fun with it that way. But one large part of my motivation for, for sort of teaching undergraduates, namely getting postgraduates *to do research with me, is not there."*

The preceding comments should not be taken as any indication that we found evidence of lecturing staff shirking their teaching responsibilities. Quite the reverse was true. The impression created from the interviews we conducted with both staff and students created the impression that teaching staff were committed to the role, were thoughtful and reflective in their practice, were active in looking for ways to improve the student experience, and recognised the value of the job they were doing. (We should say here that we recognise that our student and staff sample might not have been representative of the general population.) Indeed, in general staff gave the impression that they had a belief in the value of mathematical education and enjoyed contributing to it, and many were rather more positive than the above comment that it 'pays the rent'.

However, it would be fair to say that there was a sense from a significant number of staff – perhaps especially in the research intensive universities – of a mismatch between their own aspirations and the reality (well acknowledged by staff) of the circumstances in which we work.

This can be seen to some extent by the following quotes:

> *"So I'm not, I mean we're not training research mathematicians. We're not necessarily training mathematicians. We're training people for the workforce. But with some… some cynical people say skills like showing up on time. Things like that…"*
>
> *"Well maths is doing very well in the UK, compared to other countries in the world there are lots more students that go into university just to study maths. That's mostly a very good thing, right? And perhaps some of them just do it out of kind of inertia, they don't think very seriously about it, maths has always been their best subject at school and they sort of just assume 'okay, I'll go on at university and do more of it.' The job market for maths grads is excellent at the moment, most of them earn more than I do even, you know, a few years after university even if they don't have a very good degree classification. So I suppose those are the overwhelming reasons why students choose maths, nothing very positive, I do try to inspire them and some of them are inspired but realistically the ones who sort of have a genuine vocation and are going to go on and do research in maths are always going to be a small number."*

We note the slight air of cynicism about what we end up teaching ('skills like showing up on time'), reservations about the number of students doing maths ('mostly a good thing') and the dismissal of their reasons for studying maths ('nothing very positive'). To these reservations we could add others.

Some staff, in effect, would prefer fewer students, with higher entry standards, who were more passionate about the subject, whose desire for understanding drove them to work hard, and who were likely to go on to become research mathematicians. There is also concern expressed that we are not doing enough for the best students and have standards which are too low to ensure their preparedness for postgraduate study.

In other words, some of us would like students who are more like us.

6.3 Some thoughts about lecturers' attitudes

Although it is obvious to us, if not always to every student, let us make a comment about staff. Lecturers are human. If we respond with most enthusiasm to students who share our passions, or those in whom we can see a reflection of ourselves, this is normal behaviour. And we do not claim to be any different in this respect; what maths lecturer would not take pleasure from teaching a highly qualified, well motivated, hard-working student with a passion for maths?

However, we consider it worthwhile to make four slightly uncomfortable points about this situation.

The first is to question what the mismatch between our aspirations and the reality does to our own sense of wellbeing or job satisfaction. To illustrate this point, let us re-examine some extracts from the quotes already given, along with a few more. Any emphasis shown is ours.

> *"...what **really annoys me**..."* *"It's **not what you want** to hear..."* *"...this is **terrible**..."* *"there is a large, a disturbingly **large proportion of students**..."* *"busy bending over backwards and dealing **with the difficult cases**..."* *" it's a problem of quality..."* *[More maths students is] "...mostly a very good thing"* *[Reasons for studying maths are] "**nothing very positive**..."* *"**some of them** are lots of fun"* *"it's just as well I'm retiring [soon] because **I think my patience might break down**"*

Of course, we asked staff to talk about problems, and in effect we invited them to let off steam about any frustrations with sympathetic like-minded peers. Let us state again unequivocally: we found clear evidence of lecturers taking their teaching seriously and catering with diligence to the weaker students, but there is sometimes and to some extent a sense of irritation and resentment about this. Asked about our students, we have perhaps a tendency to acknowledge the diversity in our students by saying "Some of our students are very good, but..." and then to talk extensively about the others with language that reveals the extent to which we view them as a problem. Similar language is evident when our discussion of student entry standards is posed elsewhere as the 'mathematics problem'. So our first uncomfortable point might be to ask: who is it who has the problem? Might we be happier in our jobs if we could get on with dealing with the students we have (which we do, and do well, by and large) without an underlying irritation or resentment that some of us feel?

The second related point is that, however we may feel personally about the situation, there is no prospect of a return to an elite higher education system, even if this were a desirable thing. Yearning for a mythical paradise lost, of small numbers of perfect students is a fruitless pursuit. Furthermore, whilst we might debate the pros and cons of the expansion – or the extent of the expansion - in higher education, we should remember two important facts. Firstly, that it was always true that those students who went on to become research mathematicians were the exceptions rather than the rule – even in 'our day'. Perhaps now the range and number of students presents problems such as increased workload, difficulties catering to the ability range, and less time to devote to the high-flyers, but it also gives us a bigger pool in which to find them. Secondly, we don't just need the future researchers or first class students. Our degrees 'service' a wide range of future careers, and if recent events might make us question the need for more bankers, surely we can see a need (and a vested interest) for more future specialist mathematics teachers? So our second uncomfortable point might be: what is the point of wasting our energy bemoaning the state of the nation? We need the full range of students, with their varied aptitudes, abilities, attitudes and aspirations – both for our own job security, and for the future health of the subject as a whole.

Thirdly, it is surely important to remember that even if we feel some irritation, or if we can identify problems with our incoming students, these faults are not theirs. They have jumped through the hoops that were placed before them. They have achieved the A level grades we asked of them. They didn't design the A level or the school testing regime that many of us feel is detrimental to their education. We have sought them out, invited them to apply to us, recruited them onto our courses. If they are not what we would wish for, we should surely take care to remember that it is not their fault. Your department admitted these students; disapproving of this after the fact is unreasonable.

Finally – and perhaps most importantly – how do our views about our students impact upon them and their experience of studying maths? What messages do we give our students – explicitly or implicitly – about how we view them? When they make mistakes on their written work, how do we respond? If a student is brave enough to admit that they don't follow your last line of working, or they've never seen that piece of notation before, or they just don't 'get' what you're talking about, how do you react?

At one extreme, there might be times when we explicitly say that 'you need to go away and find out about this because I believe you should already know about it'. Whilst we wish to encourage independent learning, such a response is likely to create two impressions with the student: firstly that the tutor believes them to be deficient, and secondly that the tutor considers their deficiency to be too trivial for us to spend time on it.

Perhaps more likely is that you try to help – one way or another – the student to make good their deficiency. But in the process, do you express surprise that they don't already know this? Do you say 'but I thought you'd met this at A level'? Do you sigh at their ignorance before launching yourself on an explanation? Does your body language reveal your disappointment even as you start to help them? In other words, even when a student comes away with an improved understanding of the maths, do they also leave with a sense of your disapproval of their shortcomings? (We have no problem with students being aware of their own shortcomings; such self-awareness is an important part of education. But we distinguish between that and our disapproval of them.)

To these questions, we add one other, not from ourselves but from a colleague from one of the universities in this study, who interrupted us when we were talking about these ideas. Paraphrased, he said that it was all very well to talk about the problems with students, but

> *"how often do we tell them that, actually, they're really rather good?"*

7 Closing remarks

In the first few sections of this paper we have summarised the main concerns that teaching staff have about our students. In particular, we have noted that there are worries about their competence at basic tasks which they have met previously (such as algebraic skills), their ability to write mathematics correctly, their mathematical knowledge, their approach to mathematical problem solving, their commitment to the subject and motivation for studying it, and their study skills and overall approach to learning.

Furthermore, there is a widespread (but not universal) belief that this situation has got worse, partly because of changing A level specification and partly because of increased participation in higher education drawing in a wider cross-section of students.

That said, staff do acknowledge the diversity within the student body, recognising that some of our students are extremely able.

In the latter section of the paper, we raise questions about how we respond to the situation that we perceive. In particular, we ask whether a natural human response from lecturers to students being – by and large – rather different from ourselves might create an underlying resentment towards the situation, or worse, towards our students.

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4.0 Student support

4.1 *Student support*

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We aim for students to become autonomous learners, able to pick out the essential features of a problem, research any necessary information and construct a validated solution. For most students arriving into their first years, this aim is a far horizon with progress towards it only achievable with substantial support. With the increasing age participation ratio and consequent wider mix of students a corresponding spectrum of methods of support is needed. Some students know when they need support and have the confidence to ask for it whatever system is in place. Others are reluctant to come forward to ask, don't know they need support, or have not understood what their local support system is.

As part of the More Maths Grads curriculum theme we have talked to staff and students at 4 institutions (including our own) about their perceptions of how Maths first years operate. One of the central strands which has emerged from these conversations is support, and in this article we are going to briefly describe some of the recurring themes.

Friends

Three weeks into the course you are having trouble with the concept of a limit, or you have missed a vital stage in the solution process for an ode. What do your do? Hopefully by this time you have made one or two friends, so you could ask them, or you could seek out a member of staff. This might mean catching their eye in a tutorial, or perhaps even knocking on that initially forbidding door along the corridor.

The option with the lowest "leaving the comfort zone" threshold is to ask a friend, so it is not surprising that most of the students we talked to emphasised the importance of friends:

> *"the less successful students tend not to bond with other students"*
>
> *"friends..who knew what they were talking about....could explain it in a language I could better understand"*
>
> *"I don't think it's a good idea not to have friends when you're in this"*
>
> *"It's just that I think you have more confidence with your friends. Cos you feel they're in the same situation as you. As opposed to going up to someone who's sort of above your level"*
>
> *"our first choice is to go to our friends"*

It is interesting that speaking to a friend is not only an easier option, but also seen as a better option because they are on the same level and "speak the same language".

Perhaps the best thing that can be done initially to support students is to make sure that they have friends. Many students will naturally make friends, and we can't ensure under all circumstances that all students will make friends. Nevertheless some engineering of the dynamics of first year groups may facilitate social bonds.

The creation of conditions conducive to productive friendships can be aided by:

- An attractive induction programme,

  > *"The main purpose of induction week is to build up a community within the first years"*
  >
  > *"mainly a bonding exercise"*

- Tutor groups and group projects,

  > *"..we did things together in our tutor groups…that is how I met most of my friends…then gradually…you kind of sit down anywhere and everyone's kind of interlinked"*

- Accessible and convivial places for informal groups to meet up and work.

Some students find it difficult to make friends. This may be through shyness, natural inclination or force of circumstance. One international student for example pointed out that he did not have the same common points of contact as UK students and had found himself isolated at first when at the ends of lectures fellow students had quickly left. This implies the need for monitoring systems sufficiently robust to spot students who are isolated. As discussed below, personal tutoring systems, although helpful, are not necessarily a complete answer to this. When it is evident that a student is isolated then fellow students (especially mature students) are often willing to help, and a strong social structure within the group aids this process. Although not something that can easily be planned, the value of having a few good mature students in the group was highlighted by several staff. One such student was described as " a nucleus for most of the good practice"

On - line

Email, texting, MSN messaging, bespoke on-line forums, Facebook and other increasingly interactive websites form part of the tapestry of social interaction amongst students and, probably lagging behind on texting, MSN and Facebook, also amongst staff.

Many institutions have their own on-line systems which, in addition to providing information sources, may allow for discussion groups and other opportunities for feedback. Two of the students we talked to said that their first port of call for support would be on-line rather than face to face to friends, one to a University system and the other to a Facebook group. This emphasises the extent to which electronic communication is integrated into students' lives.

One feature of on-line communication that was raised in conversation is that there is a lot of contact between the years of a course and this has both its good and bad aspects. On the plus side, students in later years can sometimes post answers to technical queries from first years, provide information from a student's perspective about what to expect in later years, and generally encourage the building of a mathematical community across the years. A danger is that where a course is modified or assessment regulations change, students in later years can pass back information that is out of date and misleading.

Email has become a universal means of communication with students. It can save a personal visit, or lead into one in a way which is efficient for staff and less intimidating than a knock on the door for students. Prompt replies to emails (where possible) are evidence to students of a caring attitude from staff, and can foster further interaction.

Personal contact with staff

Apart from lectures and other formal opportunities, direct contact with staff can be through a knock on the office door (pre-arranged or on spec) or through personal tutor systems of various sorts.

One member of staff put it to us that students we were talking to were generally quite happy to walk up to a lecturer's door and knock, but they had volunteered to be interviewed and hence were self selecting and not typical. His view was that other students found this much more difficult. Staff were generally happy to see students when they came, either with an open door policy, or with specified "office hours". They pointed out however that it would not be viable if all students from a large group came. Students report "occasionally" using office hours as a back-up to exercise classes and support from their friends.

Personal tutor systems usually involve meeting with personal tutees at the beginning of the year with possible pre-arranged follow up at points in the year, and the option of tutees contacting tutors in between. Sometimes a tutor group project is linked in which can be useful in helping tutees to form friendships, as noted above.

One student commented that contact with personal tutors was a useful way of feeding information back and getting things sorted out if there are problems with other modules. The international student mentioned above said that, feeling rather isolated, the personal tutor system had provided him with at least one member of staff who could be his "confidante". On a big course, members of staff can have up to 30 tutees which limits the extent to which the tutor can get to know their students. Some staff reported that it was difficult to persuade students to turn up for pre-arranged follow-up sessions. Both staff and students had mixed feelings about personal tutor systems. They seem to work best when they are linked with a specific task, particularly a group task. Otherwise, for some students they can be a very good support but many students effectively opt out.

Drop-in sessions

Many courses have drop-in sessions in one form or another, staffed at certain hours of the week by either staff or higher level students. These were well used by students and thought to be helpful, a useful feature being that a different person explaining something sometimes gives a different perspective.

The following quotes are typical of the positive reactions towards drop-in sessions:

> *"It's pretty good though" "I find it, I find it useful. I find it very helpful" "You know I think they're quite good motivators as well."*
> (Students talking about a drop-in staffed by higher level and PG students).
>
> *"found to be very useful with one particular lecturer excellent at explaining"*
> (On a daily drop-in session staffed by lecturers).

Ideas that have worked well

We have looked here at a range of support methods and the reactions of staff and students to them. As would be expected, there is not a complete consensus about the best methods of support, and a range is needed to provide a good service to all students. While many students cite their friends as their first port of call for help, others go to on-line discussion groups, and some to a personal tutor. Nevertheless it is possible to pick out some guidelines on what has worked best.

- Students receive a huge amount of support from friends. The building of social bonds and informal working groups can be encouraged through an induction which has social interaction as a high priority, by group projects perhaps linked with personal tutors and by the provision of convenient and convivial group working spaces.
- On-line forums are there and will be used with or without staff intervention. If used in the right way they can provide a ready source of support and help to build the mathematical community. They do however need monitoring to ensure appropriate use and the current relevance of information provided.
- Drop-in sessions are seen as very useful by students, partly because of their guaranteed availability and also because an alternative explanation from another person can help to give a different perspective on a problem.
- Personal tutor systems work well for some students but are under used by the majority. This may be improved by linking in a project to be carried out by a group of tutees and overseen by the tutor. While some students are confident to knock unannounced on office doors, many find this difficult - possibly including those who need extra support most. Students may be encouraged to seek help in this way through email dialogue.

Further Consultation

We have distilled the comments specifically about student support that have come up in our conversations with students and staff. Although we have talked to a number of staff and students in each of four institutions, this is a small sample compared to the total UK HE environment. We would like to hear of different support methods that have been tried – perhaps especially about the use of online methods - and how they have worked out. Please contact us if you have information which would add to the picture we have given above, or if you have any other comments on what we have written.

4.2 *Peer-Assisted Learning in Mathematics at Sheffield Hallam University*

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Abstract

Students on the final year of BSc Mathematics at SHU can volunteer to act as Peer Assisted Learning (PAL) Leaders, each facilitating a small group of first year students in working on small projects to deliver a poster, an oral presentation and a written report as part of one of their semester 1 modules. A member of academic staff is allocated to each group providing support for the PAL Leader, and maintaining overall responsibility for the smooth running of the sessions. This case study describes and provides evidence for the resulting benefits for all participants involved.

Background

There are many types of Peer Assisted Learning schemes found across the HE sector, both in the UK and abroad. Most of these can be classified into two types – individual and group. The former involves more experienced students, being paired individually with one or more less experienced students in an informal mentor/mentee partnership. In the latter case PAL leaders provide support in a one-to-many group-based setting. This may be in the form of informal drop-in help sessions, where any first year student who feels they need help can meet the PAL leader. A number of such schemes in Mathematics at UK HEIs are in existence [1], some of which are identified in the reference list. A less common variant of this is where PAL leaders are assigned a small group of first year students, meeting at regular timetabled sessions to carry out specific activities. This is the model adopted at SHU.

One of the first UK HEIs to offer a PAL scheme was Bournemouth University [2]. They define PAL as simply "a scheme that fosters cross-year support between students on the same course. PAL encourages students to support each other and to learn co-operatively under the guidance of trained students, called PAL Leaders."

The opportunity arose at SHU to implement a peer-assisted learning scheme in Mathematics when funding became available to support Project based learning. First year students work in small groups during semester 1 on a project aimed at encouraging teamwork and presentational skills, and this seemed ideal as a vehicle for peer assisted learning.

Implementation

The scheme in the Mathematics programme at SHU involves final year students acting as PAL leaders for groups of first year students throughout the first semester. In the current academic session (2009-10) there are 12 final year students each of whom facilitates a group of 7 or 8 first years who are working on small projects as part of one of their modules. Each group has to identify their own project topic, and organise themselves effectively. PAL leaders encourage the groups to undertake a Belbin-style group role indicator test [3] to help them identify appropriate roles. At the end of the semester, each group has to deliver a poster, an oral presentation and a written report – these form the basis for their assessment of this element of the host module.

The project is not intended to be especially challenging mathematically to the first year students - the idea is for them to make use of existing technical skills, and develop their teamwork, research, leadership and communication abilities.

The role of the PAL Leader is emphatically not to teach the first year students, but to encourage them to recognise for themselves what they need to do - which of their group is best suited to which task, for example, and how they should make progress. It may involve asking searching questions of the group in meetings, guiding discussion or taking note of who is not contributing and finding ways of helping them get more involved. PAL leaders are provided with one day's training before the start of the semester to help raise awareness of these issues, and provide them with some practical suggestions.

The member of academic staff allocated to each group provides support to the PAL leader, and maintains overall responsibility for the smooth running of the sessions. Some choose to take an active part in the weekly sessions while others allow the PAL leaders to lead them.

Barriers and enablers

There are a number of difficulties in setting up and running the scheme. Most importantly, as with many educational initiatives, it requires at least one person who will champion the cause, devoting time and energy to motivate the participants and to stimulate enthusiasm for the scheme. A lack of resource – principally staff time – will also inevitably be a major barrier to success.

For a PAL scheme such as this that depends on regular meetings taking place, it is very helpful to book rooms so that the PAL sessions appear on students' official timetables. The constraints involved – finding times when both sets of students, staff and rooms are available - can be problematic however.

It was initially anticipated that getting volunteers from the final year student group might be a problem. These students are very focussed on their studies and are keen to gain a good degree grade, and since involvement in the PAL scheme does not – for them - provide any academic credit there was a concern that they may be reluctant to take part. During the first year of operation in 2008-9, funding was available to support the scheme, and this was used to provide an incentive for PAL leaders – they were paid £120 each. Despite the fact that no further funding was available in 2009-10, enough volunteers were nevertheless keen to take part, suggesting they felt that the employability skills gained made it worthwhile.

One other important factor in final year student engagement with the scheme is that many of the students on the course plan to go into teaching as a career. They see the PAL scheme as a way of gaining very relevant skills, and of strengthening their CV.

Once the scheme is set up and running, there is also a need to maintain an oversight of the PAL activities – otherwise there is a danger that student engagement will suffer. The Maths programme at SHU provides an e-Progress File [4] which students use on a daily basis to reflect on their course activities. Reviewing student entries in these electronic logs (for both first and final years) provides a very effective mechanism for monitoring the progress of the PAL scheme. With an effective staff-student dialogue in place, problems and issues can be tackled quickly and efficiently.

Evidence of Success (Impact)

At the end of the scheme last year (2008-9), all participants were asked to comment on what they felt were the good and bad points of the scheme, and what they felt they gained from it personally. Presented below are a selection of the responses.

1. What went well?

PAL Leaders

"Being on the same wavelength as the PAL group aided rapport greatly. It is easier to be honest and speak up to a student PAL leader as opposed to a lecturer"

"I felt I had a very good relationship with my group where they were able to speak up and voice concerns whilst also understanding what I required from them"

"The 1st years asked quite a few questions about the course in general, which seemed to help them"

First Year students:

"They were a friendly face at the start of the year that we could go ask if there were any problems with anything. We regularly talked to them about problems with other subjects or if we didn't know where anywhere was or what to do"

"We got to ask questions and see how the uni life was. As the 'Pals' do Maths too they gave us advice on what to do and what is best. As we just started it helped us to form friends. Was fun and good working as a team and different because usually in school, college we never had group leader who were a few years older"

Staff:

"Our final year students approached the job in a professional and responsible way and related well to the 1st years. The 1st years seemed to get quite a lot out of being able to chat to some final year students, quite apart from their project.

From the ones that I saw, the 1st years produced presentations and reports of, if anything, better quality than last year when final year students were not involved"

2. What did not go well?

PAL Leaders

"I don't know that having the tutor in the meetings helps ... it always seemed a little harder to take the meetings knowing that someone with far more authority is sitting next to you"

"Group a little too comfortable to let PAL leader lead sessions"

"Not all students attended the meetings"

First Year students:

"I enjoyed most of it but getting up early wasn't very good and it meant that not everyone was at the meeting (including me) sometimes "

"Sometimes it felt like we were in front of a panel of judges being assessed on our weekly activities. I felt like I was the one giving all the answers. We needed to have more discussions, but it was hard getting other group members active and involved"

"Not a lot other then the fact that some people had to do more work then others but that is kind of unavoidable"

Staff:

"I felt the tension this year between being present at meetings sufficiently much to get to know the 1st year students, and not interfering with the relationship that the final years were building with the group. In the end I didn't get to know the group as well as I would have liked"

3. (a) What did you gain from being a PAL leader?

"It's certainly made me more confident speaking up in front of a group of people I don't know. It gave me a good idea of how people work together in a group too, something that you don't notice as much if you're actually working within the group"

"Allowed me to reflect on how much I have developed over the course which will be useful when looking for employment as I can list all the skills which I now have"

"(it) improved my confidence. We started off with a group who didn't know each other. Now through good direction and advice the group are good friends and produced a good presentation"

3. (b) What did you gain from the sessions (first years)?

"I learnt that to meet new people isn't as hard as I thought"

"Learn to work in a team at a more mature level"

"My teamwork skills improved"

"I also benefited from having someone to talk about problems I had with university and things. They also told me what to expect from next year and gave their opinions about the course and the placement year"

Quality Assurance

Evaluation sessions are held midway through the semester, and at the end of the scheme in January.

Recommendations for others

From the above responses, the various benefits gained by each group of participants can be identified:

Benefits for PAL leaders include:

- developing personal skills such as leadership, teamwork, interpersonal communication, facilitation and coaching skills,
- gaining confidence especially in situations when teamwork is required to attain a goal,
- valuable experience to enhance their CV,
- experience in managing groups.

Benefits for the first year students include:

- smoothing the transition into HE by providing contact with more experienced students who can offer academic and pastoral support,
- helping with social integration,
- learning team-working skills.

Benefits for academic staff include:

helping to foster a learning community,

practical help managing the academic tutor groups, and input into the assessment process.

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7. Oxford Brookes: <http://tech.brookes.ac.uk/student-activities/mentoring/peer-assisted-learning>, School of Technology (run lunchtime help sessions)
8. UWE: <http://www.uwe.ac.uk/pal/>, University-wide (second years run weekly support sessions for first years)
9. Imperial College: <http://pubs.doc.ic.ac.uk/peer-tutoring/peer-tutoring.pdf>, Mathematics. (yr3/4 undergraduate teaching assistants, UTAs, help run first year tutorials)
10. Sussex: <http://www.informatics.sussex.ac.uk/users/og22/pal/informatics/index.html>, Informatics, (second year students run drop-in help sessions for first years)
11. Southampton: <http://www.soton.ac.uk/lateu/projects_and_funding/LTEF_project_docs/2007/UMPosterLT08.pdf> (Maths). Undergraduate mentors (UMs) run sessions to help other students.

4.3 *Peer Assisted Study Sessions for Mathematics Undergraduates*

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Abstract

The transition from school to university study can be a difficult time for many students, especially those from other cultures and families with little experience of higher education. This case study describes the use of Peer Assisted Study Sessions (PASS) in which higher year students provide academic and pastoral support for first year mathematics undergraduates, helping them to effectively integrate into university life.

The History of PASS

Peer assisted study has a long history. The Peer Assisted Study Sessions (PASS) scheme used at the University of Manchester is based on the model of Supplemental Instruction (SI) developed at the University of Missouri, Kansas in the 1970s. The SI scheme gained recognition and was disseminated in universities throughout the US and became internationally recognised throughout the 1980s. In 1993 SI was adapted for UK Higher Education, when it was first used at Kingston University. The scheme was renamed PASS (Peer Assisted Study Sessions) or PAL (Peer Assisted Learning). At the University of Manchester, PASS was introduced in the Department of Chemistry in 1996 by Emma Coe and the Mathematics Department initiated a PASS scheme the following year. PASS now operates in over 20 subject areas at the University. In 2009 the University became the National Centre for PASS, approved by the International Centre for SI in Kansas.

Why Peer Assisted Learning?

The School of Mathematics at The University of Manchester has an undergraduate population of over 1200 students of which the first year cohort is about 430, including 90 international students. Student expectations of studying for a mathematics degree may differ considerably from the reality, especially for those from overseas or from families with no history of higher education. Providing an opportunity for new students to work closely with others who have recently been through the first year experience can be very reassuring. Second year students recall their homesickness when they first arrived at university. They also report how they felt overwhelmed by the workload initially but how they adapted to the demands of study. Learning with peers helps students to develop confidence, improves communication and group interaction skills and gives students more control over their learning. It encourages an active approach to study by encouraging discussion and a deeper understanding of course material. There is substantial evidence in the research literature to support these claims, in particular see the work of Topping [1] and Moust et al [2].

What is PASS?

- There is no fixed model for PASS but all schemes have the following features in common:
- Higher year students meet regularly with lower year students to discuss academic course material
- PASS supports the learning experience by providing a safe environment for students to work collaboratively
- PASS sessions are run by students for students, encouraging a student-centred approach to learning

The PASS scheme in the School of Mathematics involves weekly classes where trained student PASS leaders, working in pairs or threes meet with a group of ten to fifteen first year students. The PASS leaders are there to facilitate the group discussion, not to teach the students or tell them the answers. The session may focus on course material but will often cover other issues such as course options, careers, accommodation and socialising. PASS is not a substitute for lectures or tutorials but provides an extra layer of support where students can work together in an informal, safe environment.

In the School of Mathematics there are currently 34 PASS groups run by over 70 PASS leaders. The leaders are mainly second year students together with some third and fourth year students. The groups set their own time to meet to suit their timetables. Activities in the PASS sessions include discussing difficult parts of the lecture notes, sharing study skills such as note-taking and problem solving, and preparing for coursework tests and examinations. Attendance at PASS groups varies but overall about 60% of first year students make regular use of the scheme.

The PASS leaders are recruited towards the end of the academic year. An expectations workshop is held in April for anyone interested in becoming a PASS leader the following year. There is no selection process but before they can become leaders the students must complete a comprehensive training programme in September (see below for details). PASS leaders receive no payment for taking part in the scheme, but there is usually no shortage of volunteers as we emphasise the benefits in terms of personal development and improving employability.

The scheme is administered by a staff co-ordinator who organises rooms and materials, recruits new leaders and delivers part of the training. There are three student co-ordinators who work with the staff co-ordinator to provide support for leaders and organise debriefing sessions. These student co-ordinators are experienced PASS leaders and they receive a small payment for this extra responsibility. Our student co-ordinators have also produced study guides, collected and disseminated advice on course options and organised social events.

The PASS scheme is supported centrally by the University's Teaching, Learning and Assessment Office. A Teaching and Learning Manager and Advisor co-ordinate the schemes in different subjects and provide training for leaders. There is also a team of interns who work closely with the staff and student co-ordinators within the Schools.

PASS leaders' contributions are recognised at an end of year awards ceremony where they receive certificates from the Vice-Chancellor and team working awards from sponsors such as PricewaterhouseCoopers.

Training for PASS leaders

It is essential that students are properly trained for PASS. The training at the University of Manchester is delivered by an experienced team called Students as Partners and is based on the SI training model developed by the University of Missouri and adapted to UK higher education by Jenni Wallace from London Metropolitan University. The training is split into four sessions and covers learning theory, group facilitation techniques, effective questioning and listening and how to deal with difficult situations. It also gives students a chance to try out these ideas in mock PASS sessions. Most of the training is cross-disciplinary but the final part of the training deals with subject specific issues. Throughout the training the emphasis is on the leader's role as a facilitator of learning rather than a subject expert and professional tutor. The training helps build confidence and shares good practice from other PASS schemes across the university.

How to make PASS a success

There can be obstacles to setting up a successful PASS scheme. Clearly it is important to get support from other staff. Two common concerns are that the scheme will replace other forms of teaching and that it will encourage collusion and plagiarism. PASS should never be a substitute for tutorials with staff. Used in the right way, a PASS scheme can make tutorials more effective by giving students a chance to cover the material beforehand in a friendly, non-competitive environment. This gives them the confidence to ask questions and engage in discussion during the tutorial. Staff may be concerned that PASS will make it easier for students to get answers to coursework and encourage collusion. This is certainly a danger and it is essential that the training for leaders sends out a strong message that this is unacceptable. With proper training, leaders will treat their role responsibly and realise that if the scheme is discredited they will lose out in the long term.

When setting up peer study sessions it is important to start early in the academic year and make sure that the first class appears on the timetable. The time should be convenient for the first year students, ideally between two core lectures in the middle of the day. PASS groups first meet in induction week or in the first week of teaching so that students see PASS as part of their regular routine. The PASS sessions may be linked to a particular course or cover all first year material.

The key to successful recruitment of PASS leaders is to emphasise the potential benefits of the role. The scheme gives leaders a chance to evidence skills in communication, leadership, organisation and team working. These are competencies that mathematics students may find hard to develop in a traditional mathematics programme. It may be difficult to recruit leaders the first time the scheme is run, but once PASS is established it becomes easier. First years who regularly attend PASS often go on to become leaders and are encouraged to do so by their PASS leaders.

What do first year students gain from PASS?

- PASS helps ease the transition from school to university. The PASS leaders can provide practical advice for surviving the first few weeks of term.
- The PASS classes give students a chance to ask questions that they may feel embarrassed to ask a member of staff. New students can be intimidated by academic staff.
- PASS helps students to develop peer support networks.
- Discussing course material and working on examples together helps to develop their communication, problem solving and team working skills.
- Attending PASS gives students the confidence to interact in discussions and benefit from expert advice in tutorials.

Feedback from first year students is generally very positive with students commenting that “PASS is great”, “I don’t know where I’d be without PASS” and even “it’s the only place you learn things”. One PASS leader remarked that “having multiple people each bring an individual approach to the same subject/way of thinking can really make a difference”.

What do PASS leaders gain from PASS?

- PASS is an excellent opportunity for our 2nd, 3rd and 4th year students to develop valuable skills in leadership, communication and team working.
- PASS leaders gain a better understanding of the first year course material. ‘Learning by teaching’ gives a deeper insight and helps them to articulate mathematical ideas.
- PASS leaders have exclusive assess to extra training through skills workshops organised by PricewaterhouseCoopers.
- PASS leaders become a central part of the mathematical community within the School. Their opinion is often sought on key decisions in teaching and learning policy.

PASS leaders comment that “you know you’ve understood something fully when you can explain it to someone else... and they actually get it!”, “Being a PASS leader has never once felt boring or like a chore. Helping people understand the maths can give you a great confidence boost, and you get useful revision of first year material.”

What do the School of Mathematics and the University gain from PASS?

- PASS can improve student satisfaction and academic performance which in turn helps to aid retention. A recent study in the Faculty of Life Sciences at the University of Manchester looked at the impact of PASS on exam

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4.4 *The Mathematics Support Centre and mathematics degree students*

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Abstract

Learning Support Centres are but one of several ways in which students can be supported in their learning of mathematics. Many universities have developed such centres in response to the difficulties experienced by students at the transition to university. These centres vary in size, location, the students they serve, how they are staffed and financed, and the nature of the support they offer. This case study describes the work undertaken to offer mathematics support to specialist mathematicians through Loughborough University's Mathematics Learning Support Centre. It explains how the Centre has become an established part of the teaching and learning infrastructure. Much of the experience gained and many of the resources developed are now available for the benefit of academics anywhere who are interested in developing or enhancing their own institutions' provision.

Background and rationale

Loughborough University has a long-established **Mathematics Learning Support Centre** (MLSC, http://mlsc.lboro.ac.uk). Formed within the Department of Mathematical Sciences through an internal faculty development grant in 1996, primarily to support mathematics service teaching to engineering undergraduates, its role soon expanded so that by 1998 it was offering university-wide mathematics support. This included support for specialist mathematicians. From rather modest beginnings, it benefited from significant enhancement including relocation in 2002 when the University Senate established the **Mathematics Education Centre** (MEC, http://mec.lboro.ac.uk) which now oversees the work of the MLSC. Further substantial development occurred in 2005 with the award of Centre for Excellence in Teaching and Learning (CETL) status by the Higher Education Funding Council for England. This award led to the setting-up of sigma[1] and enabled refurbishment and expansion of the existing centre and the establishment of a second site of mathematics and statistics support in a location that better serves some of the target student groups. An enthusiastic staff together with prolonged and committed high-level buy-in to the work of the MLSC have been features of the Loughborough Centre. Further evidence of this buy-in can be found in the University's Strategic Plan *Towards 2016* which states that "*we will be known for … cross-campus specialist support in areas such as mathematics and statistics*". Today, this thriving and well-used resource has become part of the culture of teaching and learning at Loughborough and is a focus for a wide range of initiatives. Students and staff from any university can also benefit through projects that make the Loughborough resources and expertise more widely available. This case study will focus particularly on those aspects of the centre's resources, facilities and services that support specialist mathematics students at the transition to university and will offer advice to those interested in developing something similar albeit on a more limited budget.

It has been recognised for some time that there are many students who find the transition to university mathematics troublesome. Reports from professional bodies in the mid-nineties highlighted the problem experienced by both engineering and physics students. There are now further reports describing the problem faced by other disciplines including biosciences, economics and nursing. It is important to note that specialist mathematicians are not immune. The report *Measuring the Mathematics Problem* (Savage & Hawkes (2000)) drew attention to the difficulties experienced by this group of students in some of the country's most elite departments. It provided descriptions of high failure rates, and rapid decline in mathematical knowledge and skills. It noted that even "students with good A level mathematics (Grade A or B) cannot be assumed to be competent in basic mathematical skills", and "most students have deficiencies in calculus and display a woeful lack of practice". Two of the four Recommendations in that report were that students embarking on mathematics-based degree courses should have a diagnostic test on entry, and that *prompt and effective support* should be available to students whose mathematical background is found wanting by the tests. So there is an extremely good rationale for providing mathematics support in some form to specialist mathematics students. The Loughborough Centre though does not restrict its support to students who are fighting to survive. It encourages all students whose learning might be enhanced – indeed many of the Centre's regular users are very good students who simply want to do better. This latter finding suggests that the provision of mathematics support is more wide ranging in its level than traditionally conceived, and that the mathematics support model has moved from one of remedial support to one of enhancement. This phenomenon has been discussed at length in Pell & Croft (2008). In July 2007, the UK government's National Audit Office published a report on the retention of students within higher education. Although the report was not specifically targeted at the mathematical sciences, there are several areas where it recommends that an institution can target its work in order to make a difference to student retention. In particular, the report describes that the approach to retention should be a positive one, and that it should provide students with opportunities to improve their grades rather than just addressing any gaps within their knowledge. This case study will explain how this happens in the MLSC.

Implementation

The provision of support for the specialist mathematician starts long before the students ever arrive to commence their studies. The support centre features prominently in the open day experiences for both potential mathematics students and for their parents. Staff are on-hand to explain the range of support available and to demonstrate some of the resources which have been developed. Visitors are assured that should a student experience problems the support on offer is comprehensive and of a high standard. In September of each year, around three weeks before the start of term, all new mathematics undergraduates are sent a pack containing a letter of introduction reminding them about the Centre together with a copy of the booklet *An Algebra Refresher* which was developed at Loughborough in the late 1990s. This is a workbook intended to cover all the basic algebraic techniques essential for success when embarking upon a mathematics degree and includes arithmetic of algebraic fractions, surds, solution of linear, quadratic and some higher degree polynomial equations, and partial fractions. Students are encouraged to complete the exercises before they arrive at university, but are reassured that if there are things they don't know they shouldn't let this worry them. There is a page in the *Algebra Refresher* for them to note topics causing difficulty, and to remind them to seek help once they arrive at University. In the past the workbook was distributed by the Higher Education Academy MSOR network. It is now available on line at www.mathcentre.ac.uk, and the LaTeX source code is also available upon request for anyone wanting to customise it.

Students sit a paper-based diagnostic test, organised by the Centre, on the first day of term. Most students do rather well on this test; what the test has done in the past is identify the small number of students who score substantially below the average. These are targeted by staff in the Centre and invited to visit to discuss the support on offer. Each mathematics undergraduate has a personal tutor in the School of Mathematics. Personal tutors are strongly encouraged to discuss progress with the *Algebra Refresher* during the first meeting, and to walk the students down to the support centre, which fortunately is close to staff offices, in order to show them the facilities. So, by the time students start their academic work it is highly unlikely that they remain unaware of what is on offer, where the centre is, and why they should make use of it. Personal tutors and their students receive the diagnostic test results and are encouraged to discuss these.

After the diagnostic test students are provided with a second workbook in the series – *A Calculus Refresher*. This provides plenty of opportunity for students to practise techniques in differentiation and integration. They are encouraged to do this in the early days, before the normal academic workload has really kicked-in. Again, *A Calculus Refresher* is available on-line and the LaTeX source code is available upon request. Dr Chris Sangwin (University of Birmingham) has recently announced the release of 215 on-line calculus questions in STACK format as an open educational resource. Each of the 215 generates derivative questions with random parameters and there are full solutions. These are based on the original *Calculus Refresher* and provide a further, excellent resource for mathematics students to revise and practise techniques. Information can be obtained from the FETLAR project website http://www.fetlar.bham.ac.uk.

The support centres on campus are open daily in term time for students to use. There is always a receptionist on-hand to welcome students, ensure they swipe in (the centre maintains detailed records of which students use the centre and when), and to help them locate resources. Students can use the centres to work in and to access resources between 10am and 5pm. Academic staff are available to offer one-to-one help between 11am and 1pm and between 2pm and 4pm. Around 25 academic staff from the School of Mathematics offer this support as part of their timetabled workload. Published timetables show students which staff are available when, and where staff have specific areas of expertise these are advertised (e.g. help with LaTeX, SPSS, Maple, Mechanics, etc).

The centres offer a very pleasant working environment with tables around which students can work alone or together. There are about six student PC's and a networked printer in each centre. Separate group or quiet study rooms are adjacent either for students to use, or for a tutor to work privately where an individual student's circumstances dictate this is preferable. There are extensive collections of textbooks – all chosen because they are either recommended texts for all first and second level mathematics modules, or because they offer alternative explanations. Students have commented upon the fact that this library, being much more focussed than the main University Library, is particularly helpful. A feature of the centres is the extensive collection of self-help leaflets (typically two sides of A4) covering key topics in algebra, calculus, vectors, matrices, complex numbers and so on. There are resources for diagnostic testing, study skills, employers' numeracy tests etc.

One of the two centres specialises in offering statistics support. There is both a drop-in facility and a *Statistics Consultancy Service* offering advice on designing a project, data collection, choosing appropriate statistical methods to analyse data, and interpretation of results. This latter service though is mainly for final year students and postgraduates, usually from outwith the School of Mathematics.

Mathematics support for students with additional needs is the cornerstone of the *Eureka Centre for Mathematical Confidence* – a subsection of the MLSC. There has been a large increase over the years in the number of students with additional needs and in the year 2008/9 65 students were seen, representing an increases of 55% over the previous year. The additional needs team have supported a range of neurodiverse students including those with dyslexia, dyspraxia, attention deficit disorder and Asperger's syndrome. Specialist help is available for students who have visual impairment. The Centre also offers help to students with dyscalculia, but clearly these would not be mathematics specialists!

One of the very important by-products of providing a mathematics support centre has been the associated provision of social working space. Prior to the establishment of the centre there was no working space for students within the School of Mathematics at all. The School comprised solely a General Office and staff offices. Repeatedly students remark upon the value of this working space, and the study by Solomon et al (2010) confirmed its importance in building a sense of community.

Barriers, Enablers and benefits of mathematics support

A major barrier to establishing provision like this is financial. At Loughborough we are fortunate that high level commitment and enthusiasm of individual staff have allowed the centre to thrive. Another barrier can be lack of awareness at more senior level that mathematics is problematic for many students. Ways in which this barrier can be overcome are discussed in the Recommendations below.

In terms of enablers, the significant high-level support for the activities of the centre has allowed it to flourish. Buy-in from staff in the School of Mathematics, many of whom are more than willing to tutor in the centre, has been a factor in its success. Funding sufficient to provide not only a mathematics support coordinator post but also term-time secretarial/reception staff has been very important. Enthusiasm is essential, and even without substantial funding it is possible to start to make a difference – the Recommendations below suggest several ways in which one or two colleagues can start to offer mathematics support economically and efficiently.

The benefits ensuing are manifold and include several which might not at first sight be apparent:

- a support centre can be a one-stop shop for mathematics students in need of academic support, advice and additional resources
- it provides a focus for those staff interested in supporting students better and a location where resources can be deposited and used
- a support centre is a visible manifestation of a university's commitment to supporting students and at Loughborough the University exploits this in its promotional material
- a centre can contribute to enhancing the quality of the student experience, improve retention and progression, and support a University's widening participation agenda
- a centre can bring academic staff face-to-face with students' difficulties which often are not apparent in a large lecture or tutorial nor even in a personal tutorial situation, and as such…
- … it can provide excellent professional development for staff, raising awareness of student difficulties, and the different backgrounds and experiences which students have.

The contribution a centre can make to the general atmosphere of learning should not be underestimated. Research by Solomon et al (2010) describes the unforeseen consequence of support centres in terms of colonisation of the physical space by students and the consequent development of group learning strategies. In describing how support centres can bring about a shift in the relationship with tutors she provides the following student quote:

> *"When they are in maths support, you know they're there to help people and you're not bothering them. If you go to their office, you've got your bag, there's nowhere to get it out to show them, you know there's a queue of people behind you, they were doing something before you arrived if there wasn't anyone if the queue ahead of you so you feel like your bothering them, it's their space as well and you're going into their office. The support centre is neutral ground for everybody, you've got your stuff out and they will work their way round the table to come to you, you have your work out ready even if you've put it to one side so you can flip back to it and say 'can you just help me with this' ".*

This change in dynamic goes some way to explain and to counter the argument of some staff who might argue against mathematics support by saying *"I already have office hours and the students don't come anyway!"* There is ample evidence that many students **do** use mathematics support, and perhaps this is one of the reasons why.

Evidence of success (impact)

During the academic year 2008/9 1734 students made 8023 recorded visits to the support centre. Of these 385 mathematics students made 3259 visits, representing 22.2% and 40.6% of the totals respectively. Students who visit the centre have access to feedback questionnaires made available around the centre, and reception staff encourage students to complete them. Feedback is generally very positive. More substantial evidence of impact can be found in the centre's publications including the paper by Pell & Croft (2008) which looks at the module grades achieved by a cohort of centre users/non-users. There is now a wealth of data from other universities' support centres. Where this has been published links are provided from part of the staff area of www.mathcentre.ac.uk dedicated to *Evaluation of*

Mathematics Support Centres.

Quality Assurance

In its early days, the Loughborough Centre had a Management Committee to oversee the work, receive reports from the centre manager and advise on strategy. The Management Committee included representatives from all faculties in the University. In future, the University's Teaching and Learning Committee are going to require an annual report as a condition of continued post-CETL central funding and support. With many academic staff from the School of Mathematics working in the centre, the Centre Director organises annual training sessions especially for new staff. These are vital and ensure that staff are aware of the resources available, do's and don'ts, and how to cope with problematic situations. They are used to stress the importance of dealing carefully with students who might find their first visit to the support centre rather intimidating. The staff who work on the reception desk are also trained – their outward facing role, and the fact that they are often the first point of contact with new students, means that their training is an important part of our quality assurance process. Resources developed in the centre have now been used for many years – the quality of these has been enhanced as and when it has been possible to do so. Many of the resources are used extensively outside of Loughborough and feedback from external users has also helped to maintain quality.

Recommendations for others

There is substantial evidence that many students of the mathematical sciences find the transition to university study very challenging. Students and their parents are now increasingly discerning and demanding. So it is reasonable to conclude that university departments should be taking steps to ensure that the support for their new students is of high quality and comprehensive. There is no suggestion here that the only way of doing this is to provide the students with a mathematics support centre. Other modes of support may be equal or even better responses to the challenge. Nevertheless, many universities have gone down the support centre route. For those who wish to develop or enhance such provision there is quite a wealth of experience and resources available to help.

- Firstly, it would be prudent to read the Good Practice Guide (Lawson et al, (2001)) which explains, inter alia, how important it is to be clear at the outset which student groups are to be supported, how and with what sorts of problem. The clarification of boundaries will be very helpful, especially if demand grows.
- It would be sensible to visit several existing centre to see the different ways they operate. A list of known UK centres can be found from links in the Staff area of www.mathcentre.ac.uk.
- In the first instance it is quite possible to set up a very small scale operation, or pilot, without substantial cost. By harnessing the goodwill of one or two like-minded colleagues a support facility could be established quite rapidly, especially if one takes advantage of the range of resources which are freely available. The Engineering Maths First Aid Kit is a set of quick reference help leaflets, which have now been supplemented by many more through the mathcentre and sigma projects. These can be made available to students either on paper or electronically. Whilst reasonably comprehensive, there is no suggestion that they will cover all contingencies and suit all needs, but they will buy you the time to develop additional resources tailored to your own students' needs. Flash animations, video tutorials, on-line exercises and more are all freely available (e.g. through mathcentre).
- Textbook publishers regularly send out complimentary copies of new editions to academic staff, and many of these end up gathering dust on shelves. By asking colleagues to donate unwanted but relevant and accessible texts a small centre library can soon be built up.
- It is helpful to try to garner support from other parts of the university. For example, those outside of mathematics, but who have an interest in study skills support, widening participation, support for students with additional needs, retention and progression officers etc. can become very important allies. They sometimes have access to modest pots of funding for small projects, and a bid written jointly with such colleagues may carry more weight.
- There will be colleagues struggling to teach mathematical, statistical or quantitative subjects in other discipline areas, and some of these too, being well aware of the challenges, may provide encouragement and support.
- For those interested in trying to develop a more substantial university presence it may be necessary to call upon research evidence which points to the value of mathematics support. An archive of evidence is available on the mathcentre website and is growing all the time as more and more practitioners from around the world are publishing evaluations of mathematics support activity. This can be used to support a case for developing mathematics support further. Links to the plethora of professional body and government reports which highlight challenges at the school/university interface can be found on mathcentre.
- If your centre does develop into something more than a small-scale operation it is essential that, if at all possible, a number of staff are involved. The burden should not fall on one individual. Working full-time in a support centre

can be very stressful because one is often dealing with students who themselves have personal, in addition to academic, problems.

Concluding Remarks

There is now an active and growing community of mathematics support workers in the UK and in other parts of the world. There have been many projects over the last decade which have resulted in freely available resources aimed at tackling the challenges of mathematics education at the school/university interface. Harnessing these, and the enthusiasm of some of your colleagues will enable you to make immeasurable differences to the lives of some of the students who can benefit from mathematics support provision. Good luck!

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4.5 Can Facebook be used to improve the mathematics student's learning experience at university?

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Abstract

Facebook is a social networking tool, which in 2009 reported 300 million active users. The majority of students entering university are members, as are an increasing number of their lecturers. This report presents a case study of the effect Facebook has had on a community of maths learners and teachers at Coventry University. Drawing on data acquired from multiple sources, the study found that the establishment of a Facebook community with active student and staff membership has led to greater participation and a change in student learning identities. It also raises issues about negotiation of group ownership and censorship.

Keywords: Social Networking Services, Mathematics, Learning, Web Community, Learning Environment

Introduction

Facebook (FB) was established in 2004 by Mark Zuckerberg, a Harvard undergraduate, as an on-line social space for Harvard students. FB is an internet-based communications tool allowing members to interact with other users through messaging and playing games. Membership of FB is free and available to anyone with an email address. Members can use search facilities to find other members, and share material with friends via postings on a profile page. The postings range from messages written using a "wall" facility to pictures and videos. FB supports all of the common image and video file formats and also facilitates the creation of groups and external applications. A group can be created by anyone who is a FB member, that member consequently becoming the administrator of the group. Group membership is controlled by the administrator, who may choose to invite members or alternatively allow membership from anywhere in the FB community. Many thousands of applications have already been added to FB. Although most of these are quizzes and games, one (\Tex, \LaTeX, and such \ldots) has been developed to allow \LaTeX maths script to be reproduced. Within six years, membership of FB has increased to 300 million active users (Facebook, 2009). Whilst the early growth in membership had been amongst college students, it appears that the majority of the new membership is drawn from the 30+ age group.

This paper presents a study on the use of FB by a community of mathematics learners and teachers at Coventry University (CU). A description is given of the history of this community, together with some discussion and reflection on the effect FB has had on the mathematics community at CU.

The study

Web 2.0 in education

In the early years of this millennium, the main thrust in eLearning was based around virtual learning environments and course management systems such as Moodle (see http://moodle.org) (Everett 2007). Little thought was given to the potential of social networking sites. However, the growth in popularity of this technology has forced educators to re-think their priorities. FB is now listed by the Centre for Learning and Performance Technologies as No.33 in the list of top 100 learning tools (Hart, 2009), with Moodle at No.15.

The rapid growth in membership of FB now means that students who are not members are sometimes considered to be outsiders by their peer group. Most educational establishments have at least one FB group associated with them. Some groups, such as those set up by local students' union members, have a membership composed almost exclusively of undergraduates. However, not all undergraduates are impressed with FB and prefer other tools. According to Conneely (2007): "It's [Facebook is] so bad and boring it makes Bebo look half-decent – and I've seen maths teachers using that." At the other end of the spectrum, FB groups representing Centres of Excellence in Teaching and Learning (CETLs) draw membership from those employed to teach or carry out pedagogical research.

Facebook groups at Coventry University

This section records the development of a number of FB Groups over the period from May 2007 to November 2009. This period of time overlaps four academic years (2006/7, 2007/8 and 2008/9, 2009/10). Over this time, individual students have moved from one year group to the next and some have left the institution. To provide a consistent way of referring to student cohorts the following labelling system is used:

Cohort A (CA): 3rd year students in 2006/7.

Cohort B (CB): 2nd year students in 2006/7; 3rd year in 2007/8

Cohort C (CC): 1st year students in 2006/7; 2nd year in 2007/8; 3rd year in 2008/9

Cohort D (CD): 1st year students in 2007/8; 2nd year in 2008/9; 3rd year in 2009/10

Cohort E (CE): 1st year students in 2008/9; 2nd year in 2009/10

Cohort F (CF): 1st year students in 2009/10

In May 2007, two 2nd year mathematics undergraduates (i.e. CB) at Coventry University asked a staff member employed by sigma (see affiliation at head of article) to create a Coventry Maths (CM) FB group. Their aim was to gain membership from across the maths department, in terms of both students and lecturers, in order to air views and discuss mathematical topics. Early membership of the group came from within CB, with CC students joining after the existence of the group was mentioned to them. CA students were less interested since it was immediately before their final examinations.

Membership of the group increased during the summer months so that by September 2007 it had reached 32 members (see Table 1).

Classification	Staff	Cohort B	Cohort C	Graduate
Number	5	15	10	2

Table 1:
CM Membership immediately before new intake, September 2007

In October 2007, the new intake of mathematics students were informed during their induction lectures of the existence of the CM FB group. After one week, only one student had joined the group. During the same week, five of the CD students formed their own FB group, calling it the Numeracy Team (NT) in a deliberate ploy to create an offensive acronym. At the end of October, the group was composed entirely of CD students. During this period, CD students had also started to join the CM group.

By the end of April 2008 the membership of the 2 groups was as follows:

Classification	Staff	Cohort B	Cohort C	Graduate
Number	5	15	10	2

Table 2:
CM and NT group memberships April 2008

The figures for membership of the NT group are somewhat distorted by the addition of 31 members who were not actually associated with the CU maths community and were simply friends of Cohort D who had been asked to join in order to increase membership. Predictably, most staff remained members of CM and did not join the NT group. However, several students from CB and CC joined the group. The total number of students in each cohort were: CB: 37, CC:36, CD: 33

The CM group had, by this time, posted 9 discussion topics. The topic “Help! I have a maths problem” had stimulated some varied question and answer strings. Amongst these was a question posted by a CC student: “Linear Algebra – Why?” which elicited lengthy responses from 2 members of staff. A CD student also asked “when you use the dot product you get a number. What is that number?”. It is interesting that both questions were about conceptualisation of the maths; conversely, questions asking explicitly how to answer coursework did not appear. The last update for any topic in the CM group was May 2008. The CM wall numbered 109 posts. These range from students posting links to maths websites to staff arranging convenient times for focus groups.

The NT group had, in the period from October 2007 to April 2008 posted 26 discussion topics. These ranged from football talk to lecture quotes, with no serious discussion of maths problems. The only wholly maths related topic posted was the “Mathematics Name Game” where participants had to add names of mathematicians whose first names had the same initial as the family name of the previously added name. Whilst having little or no educational value, the various topics kept the group active, with topic updates appearing on a regular basis.

Demise of the NT and formation of Coventry University Society of Maths

The offensive nature of the acronym in the NT's name, allied to the fact that it included the university's name, caused the mathematics department staff and the Dean of the Faculty of Engineering and Computing to intervene to insist the group be closed. It was suggested that the students establish an official university based mathematics society (CU Society of Maths - CUSM) with its own FB group as an on-line presence. There was a financial incentive behind this suggestion, since as an official society they would be entitled to receive some funding for their activities. The NT was closed down in May 2008. A mature CB student who was a member of both the CM and NT groups became very angry about the demise of the latter. She deleted all of her contributions to CM. Although many of the CD students were angry about the loss of NT, none reacted quite so forcefully.

On return to CU in October 2008, CD students, now in their 2nd year, decided to establish a weekly evening meeting. Several new (CE) students became enthusiastic participants. CC and CD members decided to set up a module support service, whereby students in lower years could contact them if they needed assistance in specific subject areas. This was advertised via the FB group discussion board. It should be noted that formal mentoring is not implemented at Coventry University. During the following year, more CE students joined, to the extent that they outnumbered the CD students (see Table 3). 4 CF students have already joined (as of November 2009). The CM FB group is now effectively dormant, as it has been superseded by CUSM.

Classification	Staff	PG	CB	CC	CD	CE	CF	Randoms
Number	4	3	2	3	11	13	4	11

Table 2:
CUSM group membership November 2009

Conclusions and discussion

Before the creation of the Coventry Facebook groups no maths society existed, and communication between the separate cohorts of maths students was minimal. Since the creation of the groups, there are now regular Wednesday evening social events encompassing all UGs for all three year groups, with the occasional inclusion of members of staff. The 1st years appear to find it reassuring that they can ask advice from more experienced students.

In the space of 2 years the students who had originally offended many with the NT group are now the 'respectable' face of CUSM. FB clearly contributed to the formation of CUSM, but in a very indirect way. It was only through confrontation with the faculty that the creators of the NT made the transition to being officers for CUSM. The overall experience has shown that social networking sites cannot be ignored within HE, and that they can sometimes be used constructively. In the case of CU, a FB group created by a small, but vocal, number of students, by accident facilitated the creation of a maths society where none had existed before. At the same time, their limitations compared with formal education tools such as Moodle is obvious, and their tendency to distract students from their studies cannot be ignored. It is certain, however, that social networking sites will continue to develop, and it is in the interests of those in HE to keep abreast of new developments and at least be aware of the possible benefits to be found in embracing the latest technology.

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4.6 *Progress Files in Mathematics at Sheffield Hallam University*

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Abstract

BSc Mathematics students at SHU are required to complete an electronic Progress File comprising a portfolio of work - in the form of a personal website - and a reflective logbook. In their logbook students provide regular entries for each module in which they reflect on their learning, identify what is going well and problems that need to be resolved. They are encouraged to develop an action plan to address the problems they have identified, and report progress made towards resolving them. They are also encouraged to raise issues in the logbook that staff can respond to quickly, thereby helping to develop an active, supported, learning community.

Background

There is a considerable body of research literature supporting the claim that both student achievement and the development of graduate employability skills are enhanced by the inclusion within the curriculum of structured processes that develop the ability for self-reflection. Students should be able to identify their strengths and weaknesses, formulate strategies for addressing the weaknesses and plan for their own personal, educational and career development. This applies to all academic disciplines, but perhaps has more impact in Mathematics, where students may have less well-developed skills of articulation.

Discussion following the Dearing and Garrick Reports in 1997 resulted in a recommendation that all HE degree courses should include a Progress File, defined in two parts as

- *"a transcript recording student achievement which should follow a common format devised by institutions collectively through their representative bodies,* and
- *a means by which students can monitor, build and reflect upon their personal development (termed Personal Development Planning in the consultation paper)"* [1]

More recently the Burgess review (2007) [2], recommended that *"by academic year 2010/11 a Higher Education Achievement Report (HEAR) will replace the transcript as the central vehicle for recording all undergraduate student achievement in UK HEIs. It will contain a wider range of information than the existing transcript and will capture more fully the strengths and weaknesses of the student's performance. Further work should be done on how to measure and record skills and achievements gained through non-formal learning but this, along with other student-generated/driven information, should be part of Personal Development Planning (PDP)."*

The increasing importance attached to the additional skills students should be gaining at University, over and above their course-specific skills, is further emphasised by the '*Higher Ambitions*' report, released by the Department for Business, Innovation and Skills in November 2009:

> *"But it is a top concern for business that students should leave university better equipped with a wider range of employability skills. All universities should be expected to demonstrate how their institution prepares its students for employment, including through training in modern workplace skills such as team working, business awareness, and communication skills. This information should help students choose courses that offer the greatest returns in terms of graduate opportunity."* [3]

Further support for this view comes from the students themselves. The National Student Forum, 2009 Annual Report [4], which calls for Universities to:

- monitor and formally record students' broader learning
- increase resources for, and promote of the use of, personal development plans
- provide optional modules/classes that consider how the skills and knowledge are developed

There is clearly a shared view amongst stakeholders that the use of Progress Files – and the process of reflection and action planning – is of increasing importance in raising students' ability to recognise, develop and articulate their skills.

Implementation

The Mathematics programme at Sheffield Hallam University has since 2001 incorporated a web-based Progress File system. Unlike some other e-PDP approaches, in which student reflection takes place only once or twice per semester, the SHUMaths system requires students to engage with the reflective progress on a continuous basis. Every student is expected to provide reflective entries in their Progress File for each module at least weekly - and they receive academic credit for doing so.

The use of the on-line Progress File system has spread somewhat beyond the maths course itself - during the last complete session (2008-9) there were 368 students from 9 courses involved, contributing a total of 24,932 entries and nearly 2 million words. This year two new courses have adopted the system, bringing the number of students involved to 415. In the first seven weeks of the current session over 11,000 entries have already been made.

In year one, students are expected to make entries for each module at least weekly. These entries are assessed, and provide 20% of the mark for one module. Each student receives simple weekly feedback, in the form of a mark awarded against published assessment criteria. At the end of the year students provide a longer reflective summary of their development over this time, for which they receive fuller email feedback.

In year two students continue as above, but the entries are marked every other week with the marks again contributing towards a core module. The logbook marks comprise part of a general employability element of assessment in this module, as students prepare to apply for an industrial work placement.

In the final year, the logbook assessment is built into the Project module, comprising 5% of the total marks available. This keeps the Project work higher on students' list of priorities and helps tutors to track progress.

Although entries made by each student are hidden from other students, all are visible to staff, with the system providing many views of the data. Staff can view all entries by a particular student, all entries for a particular module or simply the latest entries. Students quickly develop a culture of topping up their logbook entries at every opportunity, and so this last approach provides an extremely useful way for staff of getting feedback on lectures, for example, within hours of delivery. It also means that as a member of staff, you get a very clear idea of how your module material is being received across the whole group, and whenever a problem starts to occur it can be dealt with very quickly. This may mean modifying the way the module is delivered – which can take place starting with the very next class – or it may be a simple matter of responding to a student question. Since the system provides an easy way to reply to a student entry by email, this can be done very easily. It is much more effective than relying on staff-student meetings to gather feedback on the progress of the course – for one thing, it's much more immediate, so problems can be dealt with before they become serious. For another, it's much more representative – all students can provide comments, even those who might not otherwise have the confidence to contact staff.

Evidence of Success (Impact)

The system has been running now for eight years. At the end of each year, first year students are asked to provide a summative review and feedback of the system, for which they receive some logbook credit.

The results of this feed into the action plan for developing the system for the following year. Some selected students comments are shown below:

1. Positive comments

"While I was writing something that I was afraid of, I was becoming stronger and with more courage to face all my problems."

> *"I have found this progress file very useful throughout the year, in helping me to record my thoughts and feelings on all the modules, I have also found it useful in helping me to organise my time better by finding where my weaknesses and strengths are so I am able to see where I need to concentrate most on."*
>
> *"I also think that the progress file has helped me to develop my communication skills and to become more confident in talking about my own work and feelings on the course. It also allows you to see for yourself how you have progressed, or dealt with any personal problems."*
>
> *"The online progress file has been a huge help in making the jump from being in a 6th form to university. It forces you, once a week, to actually think about what you have done and what you still need to do."*
>
> *"From my positive comments, I was able to build on these as well as feel confident about the work. From my comments that showed I was struggling, looking back made me realise what I needed to do to improve and also build on aspects where I had problems. I could do this by giving myself targets and this is a way of recording them."*
>
> *"The logbook, looking back now, has made me realise how much I have improved, particularly in my computer skills."*
>
> *"Talking about myself the first thing that I thought it was that it would be terrible due of my problem that I faced in English language. As the year passing, day by day I was feeling more confident to write everything that I wanted to ask or everything that I wanted just to say."*

"I feel that this online diary has been a good way of looking back on how you feel you have been coping throughout the year."

"It also lets me see how I felt at the beginning of the year about the course and compare to how I feel now."

"it was a way to express my feelings without thinking of what my teacher will think about me. I like this very much and makes me more strong because when a teacher send me an email as a reply of what I wrote in the logbook I fell that our teacher really care about our progress."

2. Negative comments

"... sometimes I would be writing in the logbook just for the sake of writing in it because I knew if I didn't I would lose marks."

"... I expected responses sometimes but didn't always get them which made me question whether some lecturers actually read the progress files."

"Why should it deserve marks? At degree level, is documenting the request for help a valid allocation of the marks?"

Student perceptions of the most important benefits and problems:

	2005	2006	2007	2008	2009	All years	
Out of:	27	13	26	19	30	**115**	
Benefits							
Planning and meeting deadlines, being organised	19	7	7	7	19	**59**	51%
Assessing understanding and reflecting on it	9	6	10	13	17	**55**	48%
Receiving replies from and communicate with lecturers	11	4	13	7	13	**48**	42%
Recording work done	4	5		10	12	**31**	27%
Gaining a view of progression over the year	8	2	4	4	10	**28**	24%
Express feelings	6	1	7	5	6	**25**	22%
Problems							
Every week is too much - may be nothing to write	12	3	8	11	19	**53**	46%
Lack of feedback, all tutors should read the comments	2	2	14	6	6	**30**	26%
Too time consuming, tedious	13	4	2	3	2	**24**	21%
Forget to fill it in	7	4	3	2	5	**21**	18%
Not relevant for me, unnecessary	5	1	4	1	2	**13**	11%
Shouldn't be compulsory	1		3	1	3	**8**	7%

A further measure of success – albeit an indirect one – comes from the results of the National Student Survey [5]. The last three of the 21 specific questions address students' personal development:

Q19: *This course has helped me present myself with confidence,*

Q20: *My Communication skills have improved,*

Q21: *As a result of the course, I feel confident in tackling unfamiliar problems*

In 2008, the scores for Mathematical Sciences at SHU was 91%, 91% and 94% for these three questions, respectively. In 2009, the scores increased to 95%, 95% and 97% respectively.

Nationally, Mathematical Sciences at SHU has been ranked 1st for this area in each of the last three years 2007-9.

Benefits, barriers and enablers

Embedding personal development planning in the curriculum through the use of e-Progress Files benefits students by developing their ability to

- reflect on their learning, identifying what went well or badly - and why;
- manage their time more effectively;
- identify problem areas, develop a strategy to deal with them and report on progress made towards its implementation;
- develop skills in self-appraisal;
- take control of their learning;

An important benefit for students is also receiving personal feedback from staff in response to their comments and questions. The students' own comments, summarised above, provide evidence that this is the case.

For students, the main barrier to effective participation is their commonly held initial view that it is unrelated to their course, and lack of clear understanding of its purpose. The first of these difficulties can be addressed by engaging students in a shared discussion around what it might take to make them a more effective student, and raising their level of achievement. This way, they should realise that this will inevitably involve a process of self-evaluation, reflect and action planning to improve their performance – and that the Progress File framework represents a vehicle for achieving this. If they reach this conclusion themselves, it should follow that they are more likely to engage with the system.

The second difficulty can be tackled both by a clear explanation, repeated as necessary, of the purposes and benefits of the process of self-reflection, and by seeing (through trying it out) that it does in fact work. Once a student finds that they gain a real benefit from the system, their engagement should improve.

For staff the principal barrier is the extra time required to read and respond to comments (and to assess the entries). Although staff perception is that regularly reading and responding to the latest comments is quite time consuming, this can actually be done very easily because of the way the system is set up. Furthermore, this is offset by the benefits that follow from the rapid resolution of problems - improved retention, student satisfaction and engagement and the development of a shared community of learning.

Recommendations for others

From the experiences at SHU, there are a number of important features that an e-PDP system should have in order for it to work effectively:

- A key staff **champion** is needed to take responsibility for developing the system, and for selling it to all participants.
- It needs to be very **easy to use** (both for staff and students).
- It also needs the **active engagement of staff**. Students clearly perceive the logbook as having more value if they receive prompt replies or feedback to their entries.
- Although students understand the importance of developing employability skills, they prioritise their work according to credit received, so it is important that the logbook entries are **assessed**.
- The system needs to be **embedded into the curriculum**, becoming an important element of normal academic activity on the course.
- The **process** is more important than the tool used. Student engagement is the key and PDP should not become a tick box activity.
- Students are active partners in learning, and the purpose of each activity should be **explained and justified** to them. Progress Files are no exception!

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5.0 Teaching and engagement

5.1 Lectures, notes and student engagement

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We want our students to be as enthusiastic as we are about our subject. We pour energy into creating lectures and materials for them, and we are pleased when we perceive even just some of them as engaging positively and actively in learning. But to what extent does what we do encourage that? How best do we use our precious and in many cases declining contact time with students?

In this thread emerging from our More Maths Grads conversations with a range of staff and students at four HE institutions, we discuss the idea of engagement through lectures and notes.

Lectures

To those outside HE, and to some of us in it, the lecture appears to be the mainstay of our interaction with our students, setting their agenda and providing a major impetus for them to engage with the material. There has been a good deal of thinking about the best ways to use lecture time, exemplified by the writings of generic educationalists such as Graham Gibbs or Phil Race, and also by more specifically mathematical projects, such as the MathsTeam project.

One concern has been to produce a less passive and more active experience for students. In spite of this, the traditional lecture still seems to be predominant, partly but not entirely owing to constraints of size. We all wrestle with the dilemma that we want to be starting where the students are – whatever that means – so that our lectures are immediately meaningful to them, but at the same time we feel constrained to "get through the syllabus". Leaving aside for this article the issue of who is imposing this latter constraint, the following quotes, from students who are succeeding, are thought-provoking.

> *"When I first got here I didn't understand any of them, just like sat there copying what was being written but didn't have a clue what they were on about. And I suppose it's still like that, you just get used to feeling like that, you just get used to not understanding what they're saying at all. Then you understand it later but not right there and then, just don't have a clue what they're saying sometimes."*

> *"... you want to put your hand up and say oh, like you used to at school just constantly put your hand up and say 'can you just say that again?' Or 'what do you mean?' And, but you obviously wouldn't do that in a big lecture hall."*

We were led, then, to ask our interviewees whether a good lecture is useful, and what makes it so.

> *"Q: What do you think of lectures?*

> *A1: Depends on the lecturer.*

> *A2: Yeah, it really depends."*

Once one gets past this personalisation, particular issues begin to arise. One theme which has emerged concerns the positive role of worked or illustrative examples, to aid with the digestion of blocks of theory. Here are some typical student comments.

> *"I go to all my A lectures …if you miss an example of what he did in the lectures then you're the one who's losing out."*

> *"I don't go to many of the B because I know I am not going to miss anything, because maybe once every couple of weeks he'll do an example on the board. Unlike A where there are 3 to 4, 5 examples on the board each lecture."*

Upon further probing it emerged that B spends his lecture time reproducing printed notes on the board, and the students we spoke to were not impressed, and less moved to attend. One might wonder whether a positive effect can be achieved by putting worked examples in the notes, but consider this comment.

> *"Cos C actually writes in real time. So it's as if he's thinking while you're … like you're doing it with him rather than just being told … he's writing at the same rate as you are … you get it better because it's a different sort of pace."*

It seems a lecture can add value over notes, as long as students can see mathematics being constructed, being done before their very eyes, rather than their being presented with a finished article.

Notes

The above discussion raises the issue of notes and handouts – whether on paper or online. Practice varies widely here, even within the same institution.

Students mention some courses particularly as having high quality notes, provided online:

> *"... the notes that the lecturer puts on the internet are very comprehensive and these are gone through in the classes."*

However:

> *"Students feel that they can get all the material without going along."*

This is a central point, and raises the issue of what is the purpose of online notes or handouts, and whether it is inevitable that providing good notes will send the message that you need not attend.

One lecturer, who makes all his notes available on a website "from the word go" observes:

> *"... they seem to like having nice structured notes with equations numbered and like everything nicely titled ... there's a point at which they have to make their own decisions about how they're going to learn ... I say to them, you know in principle you could do the entire course in your bedroom if you want, but I think it's worth turning up to the lectures to listen to me talking about this stuff."*

Some students show that they think about this issue.

> *"... an awful lot of students have been asking for things to be more Internet based, as in the fact that they put up the notes and things like that. But then that can take away the sort of, sort of almost the human part of the fact of the lecturer and the sort of pupils listening."*

> *"Some people like to hear."*

Is what we are seeing here a reflection not only of the reality of student life nowadays, wherein their university course is only one feature of a busy life, but also of an awareness that different people will exhibit preferences for different learning styles?

We may ask about the purpose of online notes – for instance whether they are for students who have missed lectures to catch up, or to allow students to miss lectures, or to free students to listen in lectures without having to take comprehensive notes. Perhaps there is not a single answer – or if there is one, it is that we should acknowledge the diversity in our student body, both in terms of practical arrangements and in terms of the way different people prefer to learn, and should allow for that variety of styles in the way we provide our courses? Perhaps having done this, it is also worth being explicit with our students that this is what we are doing, and explaining why. They can then make mature and informed decisions.

There is one final point before moving on from this discussion of the role of notes. If some students are sometimes to rely upon printed notes then they need to be able to read them and understand them.

> *"Yeah, some people they just read it through hundreds of times and it still just look like garbage."*

Reading mathematics is a special skill. At least one of the current authors remembers an inspirational teacher who drummed into him that you never read mathematics without a pencil in your hand! Is this one of the skills we expect our students to simply absorb or grow spontaneously, or should it be something we teach explicitly, say through comprehension exercises?

Attendance and engagement

Attendance has already been mentioned several times. Is it a problem? First some staff comments:

> *"In the first few weeks, 80-90% of our students show up. So in the first few lectures it is usually pretty crowded."*

> *"It's quite exceptional that attendance rate let's say in week 10 is above 60%."*

While these comments are not untypical, there is even within our sample, and in any one institution, considerable variation between courses/modules, from very high to very low levels, and varying across the year.

One can raise a wry smile by creating from our interviews stereotypical student comments about attendance:

We don't like 9am. We don't like 4pm. We don't like Mondays. We don't like Fridays. I don't like Wednesday because I play footie on a Tuesday.

But we have seen earlier that students can be quite strategic in their decision-making about when to attend. In general those students we spoke to realise when lectures are giving value over and above notes or books. In some cases, academic staff members recognise that the student body is not homogeneous, for instance:

> *"Mature students have other demands on their time ... it's a matter of finding the right balance."*

The situation then is complicated. If students are engaging with the course does it matter if they are not always at lectures? The obvious answer to this is: it depends! If lectures contain vital experiences without which one will struggle to pass, then clearly attendance matters. If it is a matter of information giving, other sources can be made available, so while lack of attendance can damage or diminish one's learning it will not necessarily lead to failure.

Whatever the situation may be, academic course teams have a duty of care, notwithstanding the fact that our students are legally adults, to monitor and follow up on any students who are at-risk. The institutions we have studied do have systems, typically combining attendance data with in-year assessment data, and interviewing students who fall foul of agreed conditions. Indeed in-year assessment can prompt an improvement in attendance – or perhaps the opposite if one does too well!

At one institution, a member of staff summed up the attitude to attendance there, and in so doing mentioned an interesting initiative:

> *"I can't pretend that we've got brilliant attendance … so long as they are engaging with the work and you can often tell that from what they write in their log books, then we feel at least confident that they are still making progress…"*

This institution has an integrated online learning log system. Through this, students reflect regularly and frequently on how things are going in exchange for a small amount of credit, and the entries can be seen by all staff teaching these students. There is thus a constant stream of information on how students feel they are engaging on all modules.

Other means of engagement: tutorials and assessment

While lectures are important in the culture of our discipline, there are other ways by which we interact with and encourage engagement from our students, including tutorials (or exercise classes, problem classes, surgeries, etc) and assessment. These will be the subject of a future article, but there are two points to make here which relate to the matter of this article.

The first point concerns what one student said about exercise classes:

> *"I find that … one exercise class is worth three lectures, because you are actually physically doing the work and there's postgraduates there to help you."*

This is a re-expression of the perception that the best way to learn mathematics is to do it rather than only watch someone else do it, or indeed just look at what someone else has done.

The spirit of this comment seems particularly apposite when considering classes which involve mathematical computing. One student commented that you *"can't learn computing away from a computer"*. Others in different contexts agreed with this sentiment. This was not to query the value of lectures in such areas, but to say that ideally if a lecture involves mathematical computing, then students should have concurrent access to a machine to allow them to try out what the lecture is demonstrating. But there was at least acknowledgement that such a wish was impractical at the current stage of development.

Of course with a relatively small group, as in one of our sample institutions, one can blur the distinction between lectures and tutorials and resort to classroom teaching, but when this More Maths Grads project succeeds, this is a luxury which none of us will have!

The second point concerns assessment and how it can be used in concert with classes to encourage and support engagement. One institution has been successfully using a weekly "little-and-often" assessment pattern, and this idea has been taken up, modified and is being trialled in a different context in a different institution, administered through the weekly lecture/tutorial system. Results of this transfer of practice are eagerly awaited.

Ideas that have worked well

We have looked here at issues around engaging students through lectures and notes, and the reactions of staff and students. While the situation is complex, as one might expect, certain points are worth summarising.

- In lectures, students say it helps them to come to grips with theory if illustrative examples are given. They particularly value live examples, seeing someone do live mathematics in front of them, at a pace which they can match. It is easier to do more of this if the lecturer is not tied by the constraints of an over-full syllabus.
- Good quality online notes are valued by students as a pragmatic back-up to lectures, but for students to get the best from the provision, it is useful to have an explicit rationale for why you are providing notes, and to explain that rationale to your students. Part of this explanation should be about how the provision of notes relates to lectures, and the place of each in their overall learning experience. You can then rely upon them to make the best strategic use of the learning opportunities you are presenting.
- Attendance is important but more so is engagement. Monitoring attendance is commonplace, but there is now some growing experience of monitoring engagement with the support of web technology.

- Finally there is some interesting experience being accumulated on the use of little-and-often assessment co-ordinated with the lecture/tutorial pattern.

Further Consultation

In this article we have presented and discussed some of the comments emerging from our conversations with students and staff specifically about engagement through lectures and notes. We would like to hear of different methods of encouraging or monitoring engagement through lectures and notes that have been tried, and how they have worked out. Please contact us if you have information which would add to the picture we have given above, or if you have any other comments on what we have written.

5.2 *Small group teaching*

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If you were to ask someone with no experience of university about different HE classes, you might expect that they would have some notion of two types of classes: lectures, and small-group classes. They probably have a very traditional view of what the former would be. They might be less clear about the latter, both in terms of what a small-group class is called (supervisions, tutorials, seminars, exercise classes, workshops, PC labs - depending on the subject and the institution) and about what might actually happen in this class, although they would probably expect more of a conversation between students and tutors.

At the start of the *More Maths Grads* project, we surveyed 223 first year students in three institutions before they had had their first class, and asked them about their expectations. By and large, their ideas chime with a (traditional) split between the types of classes: lectures, they thought, would be large groups where the lecturer talks and writes on the board whilst students take notes, and small-group classes would be where students can ask questions and a tutor will help out either individually or with groups of students.

Having discussed lectures in an article in a previous *MSOR Connections* [1], here we focus on small-groups and the distinction between them and lectures. To what extent does the traditional view reflect reality? How has this model survived the increase in student numbers? How much variation is there, and should there be more? Could we improve the system?

We talked to staff and students in four HEIs, including our own, and of course found a variety of practices. Before going any further, we should mention that there is little consistency in what classes are called in different universities, so the names given here are chosen only for the purposes of clarity in this article.

Exercise classes

In three of the HEIs, this was the main form of small-group teaching. The class is attached to a specific module, students are expected to be working on exercises set by the lecturer, and assistance is available from tutors. We include in this category classes based in PC rooms where the model is usually the same.

> *"[Staff go] around, answering questions and the way we usually do that is we don't actually do the homework for them, but if they say 'What does such and such mean?' we usually say 'Well you tell me. Get your notes out, we'll have a look.' Really the purpose of these classes is to try to teach them how to learn."*

Class sizes vary between institutions, nominally being 25-50 students, although the staff we talked to often talked about poor attendance which reduces the number significantly, although sometimes we can see the positive side of that!

> *"You have perhaps nominally 50 students with 3 or 4, well, a mix of staff and post grads, but because not all the students attend it's a much smaller student:staff ratio and that should make things a bit more personal. "*

As this indicates, examples classes might have more than one tutor in attendance, and teaching staff might be assisted by postgraduate students or post-doctoral fellows. In the two post-1992 universities in our study, there is little scope for using researchers in this way, and classes are universally taught by lecturers, with one member of staff present. In both these cases, class sizes don't exceed 30.

The students we spoke to were positive about exercise classes. As one put it

> *"One exercise class is worth ... three lectures, because you're actually physically doing the work. And there's postgraduates there to actually help you."*

Sadly, we had little opportunity to talk to the students who don't attend classes. Our own experience suggests that there are students who attend lectures but think exercise classes are less important, and perhaps they are sometimes right. Timing may play a part here; at Sheffield Hallam exercise classes are usually directly after the lecture, so students have not had any time to try the exercises before the class. This ensures that students who attend practice what they should have learnt in the lecture whilst it is still fresh in their mind, but it limits the opportunities for them to think and struggle with a problem and, perhaps, encourages them to ask for help too soon. It also raises questions about the effective use of our contact time.

> *"What tends to happen is the students spend the bulk of the time trying to figure out what it is they're supposed to be doing, not making very much progress through the task and by the end of it one or two of them are ready to ask you a question. So for the tutor, you spend most of the tutorial time stood around, twiddling your thumbs … or waiting for them to ask you a question, or you might wander around leaning over their shoulder and try and get them to ask you a question but then you wonder if you're interfering, so all the time you feel as if your time's not well spent."*

As a response to that, we have experimented in some modules with holding the exercise classes just before the lecture. Students therefore have had a week to try the set work before arriving at the class. We find that the tutor is busier during the class, and attendance is improved, although as the change has been combined with a requirement to hand in coursework during the tutorial, we can't claim that it is the timing which has solved the problem. The downside is that some students have not tried the work during the week, and arrive at the class expecting to start the exercises then, but at least their lack of work outside classes is apparent to the tutor and can be challenged.

That said, all the HEIs that have exercise classes reported poor attendance, regardless of the timing of the classes. We all know that this can be a problem across the board, but perhaps the nature of this type of class contributes to the problem. If students are engaged in working through exercises individually, it is unreasonable for them to conclude that they can do so just as effectively elsewhere? Of course, they miss out on the opportunity to ask questions, but in a class of 30 with one tutor present, just how much attention are they likely to get? Are we offering them a poor experience and then complaining that they don't make use of it?

'Lectorials'

At one university, the student cohort is significantly smaller than in the other three – roughly 30 students. On paper, their timetable has a one hour lecture followed by a one hour tutorial, but because of the small number of students, in practice this is sometimes used as a two hour class without a clear distinction between the two halves. A two-hour class might consist of 20 minutes of lecturing, followed by worked examples from the homework or time for students to try examples with staff assistance, followed by more lecturing.

There are clear advantages to this approach: firstly it tackles the problem of attention wandering during a lecture by varying the activities; secondly it mimics the approach adopted by most schools, judging by the responses given in our questionnaire of incoming students, where most reported something similar as typical of their maths lessons. It may therefore make the transition to university easier.

At first glance it may appear that this system would be unfeasible with larger student cohorts, but here at Sheffield Hallam we hope to get some of the advantages of this system with an experiment starting in October where in two modules a one-hour lecture will be replaced with a two-hour 'lectorial' (for a cohort of 80-100 students). The staff resource for this will be generated by having one fewer exercise class group (with correspondingly larger groups). Whether this is successful – and whether students appreciate the extra hour's contact time – remains to be seen.

Tutorials

One university organises its small group teaching very differently. Rather than having time allocated for each module, the students in the first year have three tutorials – one per week each for pure and applied maths, and one every week or fortnight for statistics. Tutorial groups are of approximately six students, and are sometimes taken by teaching staff and sometimes by post-docs or postgraduate students. In pure maths and statistics the students' work is usually marked by the tutor, but in applied the marker may be a different postgraduate student. Students usually have one tutorial with a staff member who is also their personal tutor.

In these classes it is much less likely that students would be working individually on exercises; rather they are expected to arrive having made a serious attempt at the problem sheets and with questions for the tutor. Typically the tutor would go through exercises which are causing problems for the students on the board, with input from the students.

The students are generally appreciative of the system.

> *"…very helpful. Yeah 'cause you know the homework we get like a homework every two weeks and we go to the tutorials, and some of the questions like I have no idea about what you have to do and then they get explained to you like it makes sense then you can go away – because in the tutorials you can ask questions that you can't ask in the lectures really. Yeah they're really good."*

In general staff and students talked about the classes being primarily focussed on the latest homework sheet, although one reported that the small groups enabled a broader style of discussion.

> *"This year I've got a group who, they won't stop talking which is really good actually, 'cause it means we really have a discussion, it feels more like an art seminar, [like] it would be in my imagination anyway. And they're really enjoying that, I think if I can do that in future years it would be good. But I think it's a lot to do with the fact that these students are really engaged. But they, part of what they're saying is 'why do we have to do all this?' They really need some kind of justification, motivation to do it."*

Perhaps the biggest advantages of this system are not within the class itself but in the formation of relationships, both between students, and with the tutor. In [2] we reported that most students seek help from their peers in the first instance. The tutorial group system gives every student an opportunity for a ready-made group of peers to discuss problems with.

> *"Some of us have got this question, some of us got the other; we band together and like explain to the others like why we can do it. And they explain why they can do another question. It's quite helpful."*

Students also reported a much greater willingness to ask questions of their tutors than of lecturers:

> *"[Lecturers] don't know who you are, and I just don't see them as that accessible because I know my tutors quite well, but I don't know the lecturer apart from I sit through two hours of his talking a week."*

Nevertheless, some students described these small groups as initially 'daunting' and one tutor still finds some students reluctant to engage fully.

> *"I have this ongoing battle to make them tell me when they don't understand, 'cause I can stand at the board and like talk and jabber on and do questions on the board, but if they don't tell me when they don't understand, and I'll go 'do you understand?' and they'll nod … and I'll get to the end and go 'right, could you do that by yourselves, do you understand it?' and they'll go 'No'. So I say 'tell me where you didn't understand it', and they'll point at the beginning.*

This system is obviously expensive in staff time, even with the advantage of a large cohort of postgraduate students available to assist, and the department has itself questioned whether this is the best use of their resources. In particular, they commented on the fact that they are only able to do this in the first year, and there is therefore a significant drop in the level of support when students enter the second year.

> *"Obviously that's of great benefit to the students in the first year. There is an extent to which come their second year they'll suddenly find there's a bit of a step jump down in terms of the support they get there and I think that's hard for some students… we kind of delay the difficult step until the second year."*

Nevertheless, a suggestion to move resource to the second year at the expense of the tutorial system has been rejected – for now at least, although discussion continues. Some staff described the advantages for students, but also recognised a personal interest in maintaining the current system.

> *"One of the reasons I don't want it changed is almost a selfish reason, in that I prefer having these small groups 'cause then I can get to know the students better and I kind of enjoy it more with just a small number of students 'cause you get to know the students' personalities and, you know it keeps me interested, so there is a, there is a selfish aspect of this as well."*

Although he may consider this selfish, a tutor who knows the students well and is interested in his work must surely be to the students' advantage too. The same tutor mentioned another benefit of these small groups

> *"[If] they're in a group of thirty or whatever it is … it is not going to be noticed if they're not there… whenever somebody's not there in my tutor group, you know we all know this."*

Indeed, it was noticeable that the issue of students missing classes was mentioned less often at this university than at any of the other three. However, it is far from clear-cut; one of the other universities in this study reported

> *"We used to divide them into tutorial groups of six and have them in our private offices. And then after a while we found that the people who needed help most just weren't coming,"*

so smaller tutorial classes clearly don't guarantee better attendance. Perhaps the higher entry requirements at the university which runs tutorials ensures a better work ethic in its students.

On a similar note, we speculate that students in a smaller class are more likely to be actively engaged in the work. Students in a large exercise class engaged in individual work might consider it perfectly reasonable for them to use 'their' time reading emails or chatting with their friends about unrelated things, and it is certainly harder for a tutor to prevent it. In a class of six, this is surely much less likely to happen.

Surgeries

Three of the departments in this study – including the one which uses the tutorial system outlined above – timetable a class which is not tied to a specific module. Typically these are 2 hours per week. In style these are similar to exercise classes, although there is often less expectation that all students should attend. Nevertheless, the question of attendance was raised by staff, alongside another difficulty:

> *"You get the mixture, you get the students for whom it's really beneficial and therefore they keep turning up. You also get the high fliers who just want to be sure about the last little bit... that they quite understand. So you are playing to two different audiences there."*

In essence, these classes are very similar to the drop-in support sessions which many universities run, as we reported in [2], but there are two significant differences. Firstly, these classes appear on the student timetable in a way that university-wide drop-in sessions may not, which we speculate might help to create an expectation that students should attend. More significantly, because they are targetted specifically at first year mathematicians, students are more likely to come with similar problems, and this provides an opportunity for the tutor to break away from individual help in favour of group teaching if appropriate, so that the class becomes closer in style to that outlined in the next section.

Where this approach is adopted, it does of course require the tutors to be knowledgeable about all the modules; perhaps this is one reason why surgeries are not used in later years of the courses we looked at.

Cross-module structured classes

One university runs, in the first semester, a class which was originally intended as revision of A-level and was more structured than a surgery. Following student feedback, the class is now more closely related to core modules. Here, working on or asking about coursework is officially discouraged, albeit to different degrees:

> *"What a lot of them do is bring us their homework and ask us questions as well - I don't think they're supposed to do that, but they prefer it - and it's not up to… I told them they should use their contact time however they wanted - it's up to them."*

Clearly, where a department runs surgeries or cross-module structured classes, it is easy to blur the boundaries between the two styles of class from week to week or indeed within the same class.

This type of class offers other opportunities, which might address concerns expressed by some staff; for example the chance to draw out the connections between different subjects - to see the bigger picture that modularisation sometimes obscures - or focus on core mathematical skills which are useful across all modules, such as writing mathematics well or constructing logical arguments.

Miscellany

There is a noticeable difference in the ratio of lectures to small-group teaching between the institutions. In both the post-1992 universities, the usual arrangement is to have an hour's small-group class (from the students' perspective) for every lecture hour. In the older universities, the ratio is closer to one tutorial for every three hours of lectures. To what extent is this a reflection of historical differences between universities and polytechnics, or central university models? And more crucially, do we have the balance that we want or simply the one that we inherited? We don't have answers to these questions, but we invite readers to consider them for themselves and their own courses.

The use of postgraduate students and post-doctoral fellows to teach has the obvious advantage that, in some departments, they are plentiful and cheaper than lecturing staff. It also provides opportunities for the tutors to develop their professional skills and therefore contributes to the health of the overall maths ecosystem. But does having inexperienced tutors disadvantage the students? In general the students we interviewed thought not; indeed they often saw postgraduate students as closer to themselves and more likely to be helpful as a result.

Building on that idea, one university here has a system of 'peer assisted support sessions' and we have recently experimented with a 'peer assisted learning scheme' where final year undergraduates are used to provide additional support to first year students. Ongoing work supported by the MSOR Network by Indra Singh at the Open University and Steve Kane from Hertfordshire University will report about such schemes.

Finally, it is worth noting that this article focuses on structures and styles of class, but we have said almost nothing about exactly how we teach within the classroom; what do we mean when we say we help students when they have questions? This is, partly, simply a reflection of what staff and students said - or didn't say - to us, and perhaps we should have steered the conversation in that direction more. That said, our impression from the interviews is that, collectively, we think we know how to teach. There is no shortage of research on effective teaching of mathematics, but there are many barriers to university lecturers engaging with it. These might include our personal interests, pressure for our time, inaccessibility of educational research to lecturers with limited experience of social science language, a belief that we already know what works, or a reflection of teaching expertise sometimes being undervalued. The question remains: "are we teaching effectively, and could we do it better?"

Ideas and questions

We have reviewed the variety of arrangements for small-group teaching and it is noticeable that the variation across institutions is much wider than in our approach to lectures. As ever, we are interested to hear from anyone who does things differently again, and your views on the most successful methods.

We do not presume to say which of these approaches is best, but in summary we can identify a variety of possibilities which you may like to consider:

- General cross-module classes, provided in addition to module-specific classes - may provide an opportunity for seeing the links between different modules and developing skills which are generic to mathematics rather than specific topics.
- Surgeries can provide a forum for discipline-specific support, are popular with students, and may be used more than drop-in sessions which are open to other disciplines
- Small-group classes directly after lectures enable students to rehearse the lecture material immediately but may reduce the effective use of staff time and encourage student disengagement. Holding exercise classes at a different time during the week allows staff to establish an expectation that students will arrive prepared and can result in better use of the staff time.
- The students we talked to generally see their exercise classes and tutorials as being more useful than lectures. Are they right? Should we therefore change the ratio of lectures to small-group classes? Do you do what you do because that's the way it's always been done or because you really think it's best?
- Very small groups, as outlined in the tutorial section of this article, can provide multiple opportunities which are generally appreciated by both students and staff. Since few of us are in a position to increase the amount of staff teaching time, the questions are: what would you need to sacrifice in order to provide such small-group classes? What might you gain?
- Blurring the boundary between lectures and small-group styles of teaching has some educational advantages but may be difficult with larger cohorts. Certainly students want some smaller groups where they feel more able to ask questions, so with large cohorts some small-group teaching is required. But a longer, less transmissive, more varied style of 'lectorial' and consequently larger exercise classes or tutorials may be beneficial.
- There is a wealth of research into effective teaching in mathematics. To what extent do you engage with this - and are you given time and space to do so? Do you think you may benefit from it or believe that it has nothing to offer? Does your department value you for your contribution to teaching, or only for your research?

References

[1] Challis NV, Robinson M and Thomlinson MM (2009) *Notes, lectures and engagement*. MSOR Connections 9:1 33-36. Also available as article 5.1 in this publication.

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5.3 *Improving Student Performance in Calculus with Web-based Learning and Assessment*

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Abstract

The teaching of first-year Calculus at Queen Mary has been supported by a significant e-learning component since 2006. This e-learning involves a web-based environment that allows for (a) self-paced student learning, (b) on-line assessment, and (c) immediate feedback. This has led to an immediate improvement of student performance. Since then the setup has proved to be transferable across two modules taught by four different lecturers.

Background

In the face of changing A-level curricula, it was felt at Queen Mary that a new strategy was needed in order to adapt and maintain standards of degree courses in mathematics. In addition to the development of a programme of restructuring the content of first-year mathematics modules, Calculus I and Calculus II were identified as modules which could benefit from an e-learning component.

Before this could happen several issues had to be addressed. The content and delivery of Calculus I and II had changed very little over the past 25 years, which made it desirable to review and possibly considerably revise the whole syllabus. Lecturers of second-year modules noted that there was clear evidence of poor retention of learning outcomes from Calculus. Simultaneously, it was also felt that the overall level of mathematics included in Calculus needed to be raised.

In addition to these considerations, the School of Mathematical Sciences faced a dramatic increase in student numbers. After having had a relatively steady intake of around 130 students per year, our student intake more than doubled between 2003 and 2006, and was projected to continue its increase. It reached its highest peak thus far in 2008, when nearly 350 students enrolled in Calculus I. Of some concern was the fact that this increase was not adequately balanced by a corresponding increase in the postgraduate population, meaning that there were proportionately fewer people available for marking coursework and tutoring in exercise classes.

Choice of Platform

To improve Calculus skills, it was decided to provide a web-based environment in which students could be encouraged to engage in self-paced learning. The search was focused on well-established, commercially available solutions. This was primarily because the option of running an experimental pilot scheme was not viable, as Calculus I and II are core of the first-year mathematics curriculum, taken by more than 300 students every year. A further issue was that there was no local expertise available on how to organise a mathematics-centred on-line platform.

Introducing new e-learning methods while simultaneously processing increased student numbers presented a challenge. Having focussed the search on commercial solutions such as Maple T.A. or WileyPLUS with Webassign, we decided on using MyMathLab, the on-line support environment for *Thomas' Calculus* [1].

The motivation to use this platform was twofold. Firstly, the redesigned syllabus of our Calculus stream was very much in line with the order in which the textbook *Thomas' Calculus* presented the material. For example, we had decided on a change of syllabus which involved teaching differential and integral calculus before considering sequences and series, and thus needed a textbook in which the material was presented in this order.

The other major reason for choosing this particular platform was that the online platform and the textbook were extremely well integrated. Moreover, textbook material was available in electronic form for lecture preparation, which would enable the lecturer to achieve great uniformity across lectures, textbook, and coursework.

Additionally, we needed to get students to do lots of exercises by whatever means possible in order to lay a successful groundwork for subsequent learning. MyMathLab promised to be the correct tool for just that.

Implementation

With the framework in place, the path was clear for me to introduce MyMathLab into the new Calculus I. This setup would then be continued by the Calculus II lecturer. I had been awarded an e-learning fellowship from Queen Mary to help me with the implementation, which provided some funds to help pay for the extra work that was needed by a module administrator in setting up new support structures for Calculus.

One of the benefits of MyMathLab is the ability to provide immediate detailed feedback to students, together with a wealth of exercise-specific on-line support, such as specific step-by-step guides that break a larger coursework problem down into intermediate calculations for the student. There are worked examples available, the relevant textbook pages appear at the push of a button, and multimedia material is available where appropriate.

Although computer-controlled rather than lecturer-controlled, this setup enables the lecturer to efficiently provide formative feedback to large numbers of students. Another benefit of using an on-line system is the opening up of a possibility of switching to "mastery exams": the lecturer can set assignments that a student can repeat several times but is required to achieve a desired level of mastery in.

The students thus had a platform available in which they could chart their learning progress, deepen their understanding of the material, and test their problem-solving skills with the very large supply of questions. For me as a lecturer, the central question was always "What steps can I take to enable students to embrace this new technology to maximise their learning?"

I approached this by introducing a mixture of formative and summative assessment. First, students were given exercise problems with full access to all on-line help. While this work was not assessed, it was a prerequisite for being able to access coursework. After having worked through the exercise problems, students were given assessed coursework problems which they had to solve without any on-line help. In order to further encourage practising, I allowed for multiple submissions of the randomised coursework problems, with only the last submission counting towards the final mark.

Another change in the teaching of Calculus I and II was that there were now two in-term tests. In Calculus I, for example, covering differentiation and integration skills, respectively, with the view of eventually administering these tests on-line. Encouraged by the initial success of the e-learning platform and in order to introduce some uniformity in assessment style, I quickly decided to also set the in-term tests using MyMathLab.

While it is possible to practise calculational skills within an on-line environment, it is nearly impossible to work with "theorem and proof"-style mathematics. This was being done instead in the exercise classes, which therefore became decoupled from helping students with on-line coursework. The final exam was a conventional exam paper, however I ensured that many of the questions were similar to the familiar style of on-line coursework questions.

Barriers and Enablers

The introduction of a major change such as an e-learning component into a core mathematics module necessarily creates opposition among some teaching staff, which was somewhat counteracted by giving short presentations of the "new" Calculus at staff meetings.

A much larger barrier was actually the lack of an up-to-date campus computer network. This made installation and update of software difficult, and forced the students to click past a message claiming that the version of internet explorer used was incompatible with MyMathLab. Setting up the computer labs for the midterm tests was also quite labour intensive. (The college has since updated its network from Windows ME to Windows XP.)

We provided technology support for the on-campus network and also offered a Windows server which students could connect to from home via Remote Access (MyMathLab was not supported on Mac or Linux operating systems). While we could not additionally support students' own computers, in practice any student who had access to a computer running Windows XP and an up-to-date version of Internet Explorer was able to install the necessary software plugins relatively easily from scratch. While the majority of students worked on the college network, a large number of students took advantage of doing work at home, sometimes into the wee hours of the night.

The implementation was significantly supported by elements of the college's Learning and Teaching strategy. E-learning projects are supported by a small grants scheme (e-learning fellowships), and are explicitly mentioned in the announcement of a college teaching prize (Draper's prize for developments in learning and teaching).

Evaluation

Over the past four years of teaching the new course, approximately 1200 students registered for Calculus. Indicators for the success of the new Calculus I format are examination results, student evaluations, and, interestingly, observed effects on other modules.

The examination results were very encouraging. Even though the level of the exam paper had been raised, student performance in the Calculus exam stayed in line with other modules.

Student feedback in week six was simultaneously supportive and critical of the on-line component. Most students loved the on-line environment and praised the ability to practise, but some criticism came from students worried about an unknown form of on-line assessment. When asked directly “How do you like MyMathLab” on the questionnaires, the response was resoundingly positive with more than half of the students rating it 5/5!

Interestingly, a very positive influence was observed on student performance in Essential Mathematical Skills (EMS) - a module that students must pass in order to progress into the second year. The introduction of MyMathLab coincided with a drop in the failure rate of EMS from 4.5% to less than 2%, which can likely be attributed to increased practice using the on-line platform.

Quality Assurance

The quality of every module is assured by the subject examination board in connection with the external examiners. In the first year of running the new modules, the external examiner involved with Calculus was alerted to the changes early on and was subsequently consulted about the introduction of computer-based mid-term exams and the fact that some exam questions would need to relate to the on-line coursework questions. Overall the external examiners are very happy with these restructured modules.

Outlook

Despite the challenges faced due to increasing student numbers, the introduction of MyMathLab has turned out to be a clear success. As a result, MyMathLab has now become accepted standard for the two first-year modules Calculus I and II.

Currently, two other lecturers are fine-tuning the style of lectures and exercise classes in Calculus I and II, and are adapting the module to a changing teaching environment. In particular, the roles of exercise classes and coursework in first-year teaching are presently undergoing major changes in line with all other modules. For uniformity reasons, this has necessitated the re-introduction of written coursework and the setting of one midterm test rather than the two that had previously been the norm. Coursework now also no longer counts towards assessment, so a major concern was whether students would still engage with MyMathLab as intensively as before, especially because the midterm test would still be done using the on-line platform. Fortunately the midterm test results showed that this concern was unfounded, and that students by now willingly engage with MyMathLab.

Impact

MyMathLab has been successfully used by four different lecturers in two different modules. At Queen Mary, an Educational Staff Development course on “Case Studies on E-Learning” has included this project. Moreover, it is being used as an example of best practice in the teaching of our Postgraduate Certificate in Academic Practice, and has been shortlisted for the “Drapers Prize for the Development for Teaching and Learning”. Enquiries about the use of MyMathLab have come from other institutions in the UK such as Royal Holloway and the Open University.

There is currently considerable interest in e-learning activities regarding the teaching of calculus in the US. The American Mathematical Society has recently initiated a first-year task force, and is soliciting comments on e-learning at http://firstyearmathematics.blogspot.com/. During an extended stay at the University of Maine last year, I had discussions with the resident Mathematics Education Group, and reported on my experiences in a well-received Mathematics Colloquium presentation entitled “E-Learning and Calculus.”

The publishers of Thomas’ Calculus use our experience in advertising, explicitly referring to Queen Mary’s successful implementation of MyMathLab in first-year Calculus. A colleague of mine at the University of Melbourne reported that the publishers are currently referring to the “phenomenal success” of MyMathLab at Queen Mary when advertising their product in Australia!

References

[1] G B Thomas et. al., *Thomas’ Calculus, International Edition, 11th Edition*, Addison Wesley/Pearson Education, (2005)

Using a tablet PC and screencasts when teaching mathematics to undergraduates

5.4 *Using a tablet PC and screencasts when teaching mathematics to undergraduates*

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Abstract

I use technology in my classes in a variety of ways. I use a tablet PC and a data projector to display pre-prepared slides which I annotate during classes. I also record screencasts of my classes (movies of everything that is displayed on the screen during my classes, with synchronized sound), and I make these available to the students online, along with the annotated slides and other supporting materials. I have made a selection of my screencasts available as open educational resources. Feedback on this use of technology is extremely positive.

Background

I have taught the second-year module **G12MAN Mathematical Analysis** at Nottingham for each of the last five years, to classes of up to 183 students. As students find this material hard, I have looked at various ways to assist them with their learning.

Since 2006-7, I have used a tablet PC and a data projector to display slides which I annotate during classes. In 2007-8, I also made audio recordings (podcasts) of all of my classes. For more details concerning my earlier use of a tablet PC and audio recordings (podcasts), see my previous case study **[1]**.

From time to time, students would ask me whether I could also record screencasts of my classes. In September 2008, during a visit to Nottingham, Professor Chris Triggs (Auckland) showed me some screencasts of his own classes. The recording of screencasts in statistics classes at the University of Auckland was already routine. Much of the process is automated there, and full support is available from IT staff. This minimizes the burden on the teaching staff involved.

This year (2009-10) I have begun recording screencasts of my classes. Along with other resources, I make the annotated slides and recordings from classes available to the students from the module web pages as soon as possible after each class. Annotated slides and (audio) recordings from previous years also remain available to the students.

For further discussion of my teaching methodology, ideas and innovations, see my blog **Explaining Mathematics at <http://explainingmaths.wordpress.com**/> . I use this blog to disseminate my ideas and methods, and to stimulate discussion. It is primarily aimed at other university mathematics teachers, but it is also of interest to undergraduates.

Implementation

For each class, I prepare a set of slides on my tablet PC which include an outline of the material to be covered, but with gaps to be filled in. I prepare this outline using LaTeX, and generate a PDF file, which I then import into Windows Journal in order to allow annotation during the class. I issue the students with single-sided copies of the slides (suitably scaled). This allows plenty of room for students to make their own notes during classes. As well as the gaps, I can insert additional pages at any time if I need more room to write when I am annotating the slides. See **[1]** for more details of the facilities I found most useful when using a tablet PC.

I use a high-quality wireless microphone kit together with the screen-capture capabilities of Camtasia Studio in order to record screencasts of my classes on my tablet. There are many other options available, but this is a very portable solution.

Along with all of the other materials on the module web pages, after each class I make the annotated slides from the class available in PDF format, and I make the screencasts available in MP4 format. The web page includes details of which material is discussed in each screencast. Within any given screencast, it is extremely easy to find the place required by scrolling through the video until, for example, the relevant hand-written annotation appears. This is a significant advantage over audio recordings, and should be particularly beneficial for dyslexic students: such students can have difficulty putting separate audio recordings together with the written notes. Students watching the screencasts can also pause or rewind the recording in order to allow more time to think about the trickier portions of the material. The synchronization of the audio and video in the recording is particularly useful where I am drawing and discussing diagrams: **the final diagram alone does not tell the whole story**.

Many of the resulting screencasts are suitable for publication as open educational resources. I am making a growing number of these available directly, and also as part of the University of Nottingham's Open Educational Repository.

Barriers

The major barriers to the implementation process were the following.

- **The cost of the hardware and software**
  I am using a tablet PC running Windows Journal, a high quality wireless microphone kit, and the educational edition of Camtasia Studio. The total price comes to approximately £2000 excluding VAT.
- **The time required to learn how to use the hardware and software effectively**
  Windows Journal has an excellent tutorial, and you can learn to use its basic facilities in less than an hour. Similarly, it is very easy to make screen-capture and audio recordings using Camtasia. However, finding the right hardware and software settings and developing fluency in the facilities available does take considerable time. I have described my screencasting experiences in full on my blog, and I have also given details there of the settings that have worked best for me. I hope that this will remove some of the barriers for others. Here I mention the single most important obstacle that I had to overcome. Most of the apparent bugs that were detracting from the quality of the recordings were due to me running the tablet on battery power instead of mains power. This is because I make particularly high demands on the system when I use Windows Journal and Camtasia simultaneously in classes.
- **The time required after each class to process the materials and to make them available on the web**
  I am currently responsible myself for the processing of my Camtasia-produced screencasts and other materials. However, now that I have determined all of the settings that I need, the processing itself is fairly routine. Nevertheless, the rendering of video is a long process even on a fast PC, and some patience is required before the materials are available. My computer takes approximately as long to do this as the length of the class itself. However, this processing can be done in the background while I carry on with other tasks. I estimate that the amount of my own time that I need to dedicate to processing all of the materials and making them available on the web now comes to between twenty and thirty minutes per class.

Enablers

- The School of Mathematical Sciences has been very supportive in purchasing the software and hardware that I have requested in order to develop the teaching methodologies that I have been using.
- Information Services at the University of Nottingham (Teaching Support, IT support and the Learning Team) have been very helpful by making constructive suggestions when problems arose, by providing the significant streaming media resources needed to stream a large number of videos, and by publishing a growing number of my screencasts as part of the University's Open Educational Repository. You can find links to some of my teaching resources in the reference section below.
- I found solutions to several of the technical problems I faced by searching the World Wide Web. In adding details of my own set of solutions to my blog, I hope that I have contributed to this enabler.

Evidence of success and quality assurance

In Nottingham, the popularity and success of my use of technology in teaching mathematics has inspired several other members of staff in the School of Mathematical Sciences to use tablet PC's in their own teaching. Some members of staff are now interested in recording screencasts.

Feedback from the students is extremely positive. The table below shows the average results for relevant questions from the anonymous Student Evaluation of Teaching forms for G12MAN. You can also find detailed feedback from the 2009-10 G12MAN students on the web at <http://explainingmaths.wordpress.com/feedback/>

In this table, the responses are on a scale of 1 (strongly agree) to 5 (strongly disagree).

Question	2006-7 average (78 forms returned)	2007-8 average (58 forms returned)	2008-9 average (50 forms returned)	2009-10 average (71 forms returned)
The supporting materials (exhibits/handouts/slides/overheads/computer presentation) were effective aids to my learning	1.8	1.5	1.3	1.3
The module was well-presented	1.9	1.4	1.4	1.3

Several staff and students also nominated me (successfully) this year for a University of Nottingham Lord Dearing Teaching Award for my use of IT in teaching.

Many of the positive features identified in student feedback are as in [1]. However, the screencasts appear to be even more popular than the audio recordings were.

- Students find it very helpful to have access to the annotated slides and the recordings shortly after each class. In particular, if they suspect that there may be a mistake in their written notes, they can immediately check the annotated slides online in order to avoid wasting time.
- Students who miss classes, for example through illness, strongly appreciate the opportunity to have access to the annotated slides and the recordings at times convenient to themselves. They find this far superior to having only a copy of the notes.
- Students appreciate having the opportunity to revisit portions of the classes where they feel that they may have missed some useful spoken explanation. This is especially helpful for students who are not native English speakers.
- Students find large and clear writing helpful. This makes using the tablet particularly effective in rooms with large data projection screens. For some interviews relating to the benefits for dyslexic students, see the web page <**http://www.nottingham.ac.uk/dyslexia/video/browse/person/361/**>

Recommendations

If you are prepared to invest the effort required, these methods of teaching are highly rewarding. Your students will strongly appreciate the provision, and you will be able to produce high-quality learning materials which can be made available to a wider audience.

The following recommendations and issues are worth considering.

- A data projector can only display one screen at a time. If necessary you can scroll back through the preceding material, or display the slides at a smaller scale. To some extent you can use dual projection facilities where these are available (though the recorded screencast will only show one screen). Even so, the amount of material visible at one time is far less than there would be on a good set of blackboards/whiteboards.
- The microphone generally only picks up the voice of the teacher, and not the students' responses and questions. It is best to repeat what the students say both for the sake of the recording, and also for other students.
- While many students appreciate and take advantage of the materials available in order to improve their understanding, other students may stop attending classes, and may fall behind. (Even some students who **are** attending my third-year classes have said that they are a long way behind, but they are planning to catch up later.) As a result, some students may end up doing worse than they would have done if less material had been made available. One way to address this problem may be to have appropriate class tests or assessed coursework to discourage students from falling too far behind.

On the technical side:

- If sufficient technical support is available, it is best if you can concentrate on giving the class, and leave the settings and the processing of files to staff with the relevant training.
- Otherwise, be prepared to invest a significant amount of time determining the software and hardware settings which work best for you, and processing the resulting files. You may find it helpful to read my blog entries in order to facilitate this process.
- **Make sure that you run your tablet on mains power and not on battery power during classes!**

References

[1] J.F. Feinstein, Using a tablet PC and audio podcasts in the teaching of undergraduate mathematics modules, case study, in Giving a Lecture, Exley and Dennick (April 2009)

This case study is also available in adapted form from the web page <http://www.maths.nottingham.ac.uk/personal/jff/Papers/>

- A selection of my screencasts can be found on the page <http://explainingmaths.wordpress.com/screencasts/> or from the University of Nottingham's YouTube channel mathematics playlist at <http://www.youtube.com/view_play_list?p=A9721D7E1FB7CD34>
- Several of my presentations are available from the Nottingham U-Now pages at <http://unow.nottingham.ac.uk/ >
- My blog, *Explaining Mathematics*, is on the web at <http://explainingmaths.wordpress.com/>

6.0 Assessment

6.1 *Coursework, what should be its nature and assessment weight?*

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Introduction

Opinions differ about the nature, frequency and relative assessment weight of coursework in a mathematics degree. Short frequent courseworks may aid week by week engagement while a smaller number of longer tasks may be better linked to real applications and give more opportunity for open ended questions. What should be the mix between assessment types? To what extent is copying a problem and how should this be balanced against the opportunity coursework can afford for investigation and originality?

Given the heavy dependence on marks for motivation, the award of some credit to formative assessment encourages students to engage with course material. Colleagues see the advantages of frequent small tasks with rapid feedback as aiding students both to keep up with material delivered at a far faster pace than at school, and in encouraging attendance at tutorials.

Conversely a smaller number of longer assignments encourages reflection about the interrelation of different parts of the course material and gives practice in the various stages of applying mathematics. Student reactions generally support colleagues' views about the merits and possible limitations of each approach.

While at some institutions coursework is an integral part of summative assessment throughout the degree, in others it is seen, with the possible exception of a final year project, as something mainly for the first year.

This article presents a summary of views from colleagues and students about coursework and its role in motivation and assessment. These are gleaned from the interviews the HE curriculum team conducted at our own and partner institutions and all quotes come from these interviews.

Marks, motivation and assessment weight

It is a truth universally acknowledged that a student motivated to complete an assignment must be in want of some marks. Overstated, but there is certainly a lot of support for that view:

> *" The largest group of students are probably the ones who if it's not assessed, they're not going to do it."*
>
> *"If I hand it in at five past ten will it still get a mark?"*
>
> *"Getting them to do the tutorial questions is the hard thing. It's always a problem, ..., if it's not assessed."*
>
> *"They don't get a mark, they don't do it."*

This fixation with marks is seen as a possible consequence of the emphasis on accumulating coursework marks in school.

> *"By the time people have come to us from school, they already have it absolutely ingrained in them that coursework is for marks."*
>
> *"Yeah, every mark counts. ...It's like money to them or something."*

Nevertheless there is still the feeling that subject interest rather than marks can be a motivator:

> *"Enthusiastic students tend to be quite motivated just by their enthusiasm."*
>
> *" in my six, yes, there I do get the impression that, that they're not doing it just because we give them marks".*

Assignments are clearly sometimes valued for their own sake.

> *"The assignments have been great. They really built confidence and were quite a lot of fun to do."*

A contributing factor to the general reluctance to do things which don't carry marks is the need to be selective in the face of many competing calls for time, and students feel that mathematics degrees tend to have a high workload.

> *"The workload in Mathematics is so much higher than it is in all the other subjects."*
>
> *"It's a lot more hard work than I thought."*

Sometimes, the priority placed by students on marks is seen as indicative of a lack of genuine subject interest. Given the time pressures however it is not unreasonable for a student to feel that they should be able to express enthusiasm for their subject by doing something well which actually counts towards their degree.

A problem with giving a substantial proportion of the overall credit to coursework is the verification of its originality. One way round this is to make the coursework percentage small, 15% for example is

> " just enough to motivate them to actually do it and put a bit of effort into it, but it's not so much that we need to worry about them just copying it off of their friends".

Another approach is to increase the weight given to coursework, but to make the tasks individual in some way, either by having different tasks for each student (eg using randomised data) or by making the task sufficiently open ended so that no two answers should be the same.

Interpretation of marks also needs a re-think from A level, it can take students some time to realise that they are unlikely to get 100% and that they are actually doing very well if they get a mark in the late 60s.

> *"At A level I could understand everything, ... but the homeworks were like there were some questions I just didn't understand at all .. once I realised that I wasn't gonna get like 100% all the time...it's not as much of a big deal now when I can't do something."*

Frequent short coursework

At two of the institutions we talked to, coursework was set on a frequent basis every week or couple of weeks. Problems encountered included scalability of the marking process for large student numbers, setting the level to provide challenge while still being accessible to the majority, giving an appropriate place to on-line assessment and coping with copying.

With a small class, it is straightforward for the lecturer to mark small courseworks on a weekly or fortnightly basis. With a class of 300 this is clearly impossible and a team approach to marking must be taken, which can be difficult when

> *"you're managing...different markers of varying skills".*

The marking process necessitates the production of rigorous sets of

> *solutions for tutors and markers that are not the same as for the students".*

This to some extent constrains the type of questions being asked since students need to be steered to produce answers in a reasonably standard form.

Nevertheless careful organisation can produce impressive turnaround times with one institution having a weekly cycle giving out, collecting in, marking and returning work all within the week. In another institution students were divided amongst small tutor groups which met weekly, and a variant of the team approach to marking was to have tutors marking their tutor group's work. Advantages of this were seen to be that the tutor knew how their students were performing.

> *"if I mark the stuff every week, then I, I roughly know what's going on in their minds",*

and also that feedback can be more meaningful

"if there is anything particular that they think the students are missing...they can feed that straight back to their tutorial group".

In contrast, a tutor who was not responsible for marking their group's work noted that it was more difficult to keep track of whether their students were keeping up because they only know that work had not been handed in when the rest was handed back.

Judging the correct amount of challenge and credit awarded can be difficult, as a colleague reported an impression from students:

> *"there's a sort of fine line between being challenged and you know finding that exciting, and then there's only a small bit further where you just feel like you're drowning and think you can't understand any of this".*

Initially short assessments of a diagnostic nature are often given to ensure students have a common set of essential mathematical skills, and the level at which these are set reflects the common starting point assumed for the course. As the course proceeds, perceived difficulty is often linked to similarity between homework exercises and those worked through in class. A pragmatic tutorial structure which seemed to have worked well was:

> *"...first section .. a set of worked examples, ... second section..a set of questions that they're going to tap in on in tutorials, ... and then finally, ...homework questions for them to tackle, which are not entirely unrelated to the ones they'll have seen in the previous two sections".*

A small coursework percentage when spread between many assignments may not be sufficient to persuade some students to hand in a specific assignment which may only be worth 3% of the module mark:

> *"they see it as [just] one zero rather than as a long scale".*

Students want to feel sufficiently rewarded in marks terms for the effort they have put in to meet the level of challenge presented to them. After a more than usually difficult homework a colleague speculated on why the hand in rate was low in their, normally conscientious, tutorial group:

> *"one person will have said, 'Well why don't we just not bother' and they'll just have gone, 'Yeah.'"*

Even with marks attached, students are not used to not being chased for work and this takes some adjusting to:

> *"no one's gonna make you do it now so it's just the exam that will come back at you if you've not done the work"*

> *"it felt like nobody cared and I just had to get on with things".*

Having coursework on-line is useful both for automating the marking process and in providing rapid feedback. Sometimes it is done in staffed lab sessions:

> *"we have 7 hours of computer lab sessions where they get to do coursework ... with the assistance of teaching assistants".*

In other cases the online material is interactive and designed to be done independently. This however leads to a reconsideration of the purpose of exercise classes:

> *"How do you fill the exercise class now that it's no longer really necessary for coursework?".*

Ideally the free time could be used to consider additional material of interest to the module, however the exercise class then

> *"becomes an unassessed component and that automatically means students don't show up".*

Students warned of the danger of the knock-on effect in exams of on-line coursework in which the answer could, to some extent be guessed:

> *" ..in the exam, if that question comes up, You may know the answer .., but the actual working out you won't know. So you just get that one mark, you lose the other seven or eight marks."*

A useful feature of on-line coursework is the potential to randomise the questions and thus make them individual:

> "Lovely thing is that all the problems are randomised. No two students have identical courseworks. No simple way of cheating by copying".

This is one answer to a problem that is difficult to control with large student numbers when scripts are

> "farmed out in batches ...you might not always notice".

Overall the model of having frequent (weekly or fortnightly) coursework with solutions available was seen by both colleagues and students as having substantial merit. A student commented:

> *" I do like the structure ... in the sense that there is something to do every week and you know what you've got to do."*

and, on the return of work and availability of solutions:

> *"It's always the next week." but "if you want to go check, instead of just waiting to find out what you've got, you can go and check and see".*

Colleagues felt that the tutor marking system had an effect on attendance:

> *"almost 100% attendance record from the students. ....partly helped by having tutorials before where it has to be handed in",*

and was manageable:

> *"I can cope with marking 6 pieces of work".*

How popular the model however

> *"to some extent it depends on .....how good their tutor group actually is".*

One colleague again highlighted the copying problem:

> *" weaker students copy a lot, so it's not clear what the real benefit is of the course work".*

It was also pointed out that from the marking point of view, with a large group, short standardised courseworks are the only viable option:

> *"deep and longer course works would be good but you'd have to have the people to mark them ....I don't think we could do that actually with, say, PhD students".*

Longer Assignments

Notwithstanding the viability and feedback issues discussed above, the prevalent pattern in the other two institutions we talked to was to have a small number of much longer courseworks in each module, although one of the two institutions used longer coursework as part of a mixed strategy:

> *".... you'll have things like phase tests, um bits of extended coursework, short bits of coursework."*

They tended to count for a higher proportion of the total module marks:

> *"the faculty policy is to give first years mostly coursework",*

in contrast to the 15% cited for short assignments above, and were seen as giving students the opportunity to look deeply into particular problems, often related to applications. As with shorter assignments the amount of challenge has to be carefully thought through. One colleague told the story of an instance in which students' understanding was tested by asking them to explicitly write down some terms in the series solution to a difference equation. This seemed only a small stage on from deriving the general series, but caused the students a lot of difficulty even though they had the correct general form.

Two practical problems with longer assignments are estimating how long they will take students, and the length of time taken to mark them. A colleague commented that they had no standard tariff for how long it would take students to write a given number of words. One student had complained to them that 4000 words would take too long, but after having completed the assignment said that in fact it had only taken about 15 hours, which was about right in terms of the total balance of work on the module. As noted above, it is difficult to have a team approach to consistently mark more open ended assignments which are not amenable to producing solutions in a highly standardised form to mark from. This means that the marking is carried out by the module tutor - or perhaps split between two people marking different parts of the assignment. Although the fewer number of such assignments - typically two or three per module - releases some marking resource it would be unviable for very large groups:

> *"there's a resource implication to a lot of these, anything where you're trying to do something which is personalised assessment…".*

The importance of making a clear link between what is required in an assignment and the lecture material was noted by one student:

> *"we'll get an assignment that is all about the bit of work that we've just done. So makes it pretty obvious what is wanting to be done".*

This is in contrast to a module where it had not:

> *"The two assignments that we had were very tangential to the work that we'd done in lectures. ...And I don't think that's helped."*

Longer assignments can involve a number of different types of assessment, including investigations requiring students to research some information and/or to apply some mathematics:

> *"people have got different forms of words for this - they call it project based learning, enquiry based learning, all of these things are being brought together".*

Putting together such an assignment often helps to develop key skills:

> *"There's also bits of coursework that's been writing reports and researching reports ....that's something that I'll be able to use later on as well."*

Longer assignments also give the opportunity for group work, which is useful in fermenting discussion about mathematics and developing group working skills but can have its problems:

> *" it's difficult because it's group work and not everybody always puts in the same contributions, ... I've ended up doing a lot of work".*

Conclusions

Students largely put their effort in where marks are awarded, and there is general agreement amongst staff and students that frequent small assignments in the first year promote engagement. The key to this is rapid turnaround which requires a high degree of structure in the assignment and a good well organised team of markers - perhaps more viable in a department with a number of research students. Since for the marking to be viable, such coursework cannot be open ended the weight attached to it tends to be relatively low, typically 15%. This low weight means that the problem of copying is less significant, but may not always be sufficient to motivate when spread over a large number of assignments. On-line assessments are useful for rapid feedback and the possibility of randomised questions.

Where courses employ longer, less frequent assignments these generally come with greater weight, typically up to 50% in the first year. To justify such a weighting, this type of assignment must contain some material with significant challenge, perhaps by including an open ended element. Advantages can be that students come closer to the sort of mathematical process that might occur in a work situation, and that key skills are acquired which are transferable to other contexts. A disadvantage is the staff resource needed for marking which makes it difficult to operate for large groups.

Good Ideas

Despite the constraints of size, the concerns about copying and the obsession with marks, much effective assessment is clearly taking place. Amongst those things which seem to work especially well were:

- Weekly short coursework cycle including marking and feedback,
- Randomised on-line coursework with the proviso that the answers cannot be guessed,
- Structured examples/assignment sheets which move from worked examples to tutorial questions to related assignment questions,
- Tutor groups with tutors marking their own group's work,
- Longer courseworks with a clearly indicated starting point in lecture material and with additional skills elements,
- A mixed diet of coursework including both shorter pieces with rapid feedback and longer pieces with a more investigative element.

6.2 *Assessment and Retention*

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1. Introduction

Assessment schemes, attendance monitoring, and methods for dealing with extenuating circumstances, late submissions, referrals and failures together constitute the regulatory framework within which students operate. This framework should both maintain standards and encourage all students to perform at their best, a difficult balancing act given the twin contexts of international competition and wide student ability spectrum. In this article we look at how the sometimes competing purposes of assessment are manifested in various assessment schemes. We also look at the trade-off between viability, rigour and flexibility in systems for dealing with students who are, for diverse reasons, not meeting course requirements. The discussion draws strongly on the opinions of colleagues and students expressed in interviews conducted for the HE curriculum theme of the more maths grads project at our own and partner institutions, and all quotes come from these interviews.

2. Requirements for Assessment Schemes

How good are our best students, and how do they rank with those from world-leading universities? One colleague drew a general comparison between the situation in the UK and elsewhere, stating that in the UK

> *“vastly more people, study university mathematics...... that’s mostly a good thing, but of course it does mean that standards are inevitably lower” although “some of, the best of our students are pretty good”.*

Another colleague, talking about their best students made the point that

> *“they’re not necessarily really in a good position to do a PhD in competition with other people”.*

A contrary opinion however, bearing in mind that several UK universities are generally acknowledged to be of world leading class, was expressed by a third colleague

> *“I would say every year I see 4 or 5 students who .....who could hold their own in any university in the UK ...could definitely go on to do research.”*

These views evidence a lively debate and real concern about comparative standards and make the point that, whatever else happens in the HE environment, we mustn’t lose sight of the need in the UK for world class mathematicians who must be verified as such by the assessment that they undergo. As one colleague put it

> *“the rate of success on the course is very, enormously variable, and we have the feeling that our best students are actually not being stretched enough”.*

It is important however that this requirement to guarantee the quality at the top end of the ability spectrum is reconciled with the need to have an assessment scheme which is suitable for all.

> *“We treat an incredibly wide spectrum of students. We have students here who could probably even, let’s say, compete with Oxford students. And we have students here where I’m amazed of how they managed to get through the A Levels.”*

The nature of mathematics degrees varies considerably from the highly theoretical to the more practical and technologically based and to some extent these differences reflect the differences in required entry grades. Two of the courses we looked at, run by new universities and of a practical nature, had published entry requirements of 200 and 240 tariff points, although they might vary in practice: “that’s what we’ll make an offer on and then come clearing ..” Two others, run by older universities and of a more theoretical nature, had entry requirements of 320 and 340 tariff points, but again these might not be cast in tablets of stone: *“so whilst we ask for a B and 2 Cs, we actually go somewhat below that”*.

As well as those who perform consistently highly through school, some students who enter university with modest grades develop or find motivation over time and prove to be able researchers. Most students graduating from mathematics degrees however will not continue on to research. A committed student who has a good understanding of the wide utility of fairly standard mathematical techniques may not be a mathematical high flier, but may make an excellent employee in a generally mathematical environment such as credit scoring, or analysing health statistics or management information.

At the other end of the spectrum there will always be students who struggle throughout. With appropriate support they may eventually attain a reasonable degree, or perhaps change course or leave and return to study later. The least desirable outcome is that they fail two or three years into their course.

In summary, good assessment schemes must identify and validate the very best mathematicians, including those who develop late, pick out those with excellent practical mathematical skills for employment, provide reasonable chances to recover failures and bad marks without compromising standards, and find and inform early those who are very unlikely to succeed.

3. Factors in designing assessment schemes

In attempting to characterise the requirements of assessment schemes there is a danger that we are looking for something that is all things to all people but is unrealisable. In practical terms there are a number of decisions to be made in designing a scheme. How is the balance between examinations and coursework managed? What is the place of testing of mathematical fundamentals in supporting those with a weaker background in the initial stages of a course? How do we gauge the step up in standard between the years (particularly first to second year) to give the appropriate amount of challenge while remaining accessible to the large majority? Should assessment be modular or lumped together at the ends of years (or even just the end of the first and third years)? What compromises are there to be made between maintaining standards, having a scheme with common elements used on several diverse courses and flexibility for reassessment and course change?

3.1 Exam/Coursework Balance

In a previous article on coursework [1] we briefly addressed the coursework/examination balance noting that small coursework tasks with one right answer should be weighted fairly low - typically between 10% and 20% of a module assessment -while longer, open-ended coursework assignments might contribute much greater percentages. In fact among the institutions we looked at (including our own) coursework weightings varied from 15% in the first year with none in subsequent years, to a broad average of about 50% in each year. The problem of coursework copying can be ameliorated to a large degree by the use of substantial open ended assignments, particularly appropriate in a more practically or technologically focussed module. Such open ended assessments are valuable in giving students the opportunity to exhibit competence in the use of core techniques and technology and also the capacity for original thought. Hence it is difficult to frame general rules about exam/coursework balance, this being determined instead by the precise nature of the material being taught.

3.2 Testing of fundamentals

Often in the first stages of a course students will have their command of fundamental “A level” techniques tested.

> *“They have to sit a test in the first week, multiple choice. If they get twelve out of fifteen right they’ve passed, if not they have not.”*

This is seen by colleagues as a useful device for ensuring that students with a weaker background on entry receive appropriate support. At one institution a diagnostic test in induction week was combined with a “revision” session on A level topics

> *“ the first two days is spent going through the algebra book.. and then on the next day we go on to the calculus books”.*

At another institution opportunities for taking a test in “essential mathematics” are repeated throughout the first semester up to a final opportunity in early January:

> *“If they don’t pass it then, they will have to drop one of their other modules and keep on trying .....”.*

This scheme has proved effective since in the year it was introduced the performance on two modules involving calculus was compared with previous years and exam marks

> *“went up by ten percent across the board”.*

At this institution what is perceived as being particularly important is the persistence in ensuring that students are secure in the essentials before proceeding. For more details of this scheme see [2]. More generally, some sort of testing of fundamentals contributes to an aim in the first few weeks

> *“to keep everybody going along and give them support in that”.*

3.3 First to second year transition

Much attention has been given to giving students as smooth an induction as possible into the beginning of a course and arranging support informed by diagnostic assessment. Another critical time in the course however is the transition from first to second year.

> *"I've found with my tutees, a number of them have said to me that they've actually found the step from year one to year two harder than the step from 'A' Level to first year." "They often do worse in their 2nd year than in their first year and then they pick up again in their 3rd year."*

In terms of exam results one colleague noted how, in the linear algebra stream of a course, very good exam results in the first year

> *"every year I think 'next year I should make the exam a little bit harder"*

were followed by

> *"noticeably poorer results in the second year".*

This was puzzling in view of the fact that the conceptual leap needed for first year linear algebra seemed greater than that to get from first to second year.

Colleagues speculated on why the second year can be unexpectedly challenging. It could be connected to common changes in personal circumstances

> *"in many cases, they're moving out of student accommodation into private houses"*

or possibly to the

> *"bit of a step jump down in terms of the support they get"*

since resources are often directed more to the first year.

This clearly difficult transition impacts on both first and second year assessment, particularly examinations. First year assessment must be sufficiently demanding to verify that students are properly prepared for second year studies. It is tempting to think that when students pass a module, they are then competent in all its aspects, but with the usual pass mark of 40% this is often far from the case. Ideally then the assessment should be designed so that to obtain 40% students need to be competent in those aspects most essential for the second year. Second year assessment must take into account the perceived difficulty in first to second year transition by setting realistic expectations.

3.4 Timing of examinations

While coursework is generally spaced out throughout a module, examinations are normally at the end. Where a course is semesterised, and modules all fall within one semester, this presents a choice of assessing first semester modules at the end of the first semester or at the end of the year. Putting exams for first semester modules at the end of the second semester is clearly unpopular with some students

> *"You're doing four modules this semester, then you have to wait all the way until May to do the final exam.... I don't like that." "In total you're doing eight exams in May.... that can put a lot of pressure on the students."*

Contrary views were however expressed by other students:

> *"I find that .. learning something and then leaving it and then going back to it, makes it sort of more long term memory."*

> *"Next semester, a lot of the work is going to be building on the work we've done this year. .. so it's going to help you in final exam."*

Colleagues had serious reservations about having exams too frequently

> *"It totally destroys the feeling that Mathematics has unity.",*

> *"It's very much an attitude ...you chomp your way through a certain amount of material and once you've done well enough then you forget it."*

There is a feeling that students become used to

> *"being able to leave it till the last minute",*

in a modular system at A-level where credit is accumulated piecemeal;

> *"Once the exam is over they can forget that stuff and move on to the next box."*

They are also used to being able to retake an exam

> *"three, four, however many times"*

without penalty.

Student opinion then is split between wanting exams as soon as possible after the end of a module and collecting them all at the year end. Amongst staff however the feeling seems to be that to preserve the unity of the subject and to allow students to understand all the interconnections between modules it is better to collect exams together. Of course it is not only the function of assessment to establish interconnections between modules. Inevitably in a modular system material in separate modules will be seen as distinct unless overt efforts are made to establish links. Nevertheless a single annual examination period has the consequence that students are revising material from different modules at the same time which gives them at least the opportunity of seeing overall coherence across the discipline.

3.5 Overall assessment schemes

As well as the positioning of exams and the balance between exams and coursework, important features of overall assessment schemes are the weight given to each module, the balance between years and the amount of "redundancy" allowed. In the institutions we looked at there is considerable variation of approach from a tightly defined scheme requiring all modules to be passed for an honours degree, to schemes allowing much more flexibility and the possibility of failure in certain aspects. This latter approach is supported by the Mathematics, statistics and operational research benchmark which states that a student having some modules with quite low marks in a profile of overall excellence may be judged to be of high overall quality [3].

UK universities work to a standard of 120 credits per year giving a total of 360 credits during a degree course. How many credits are required to actually qualify for a degree varies however. At one institution the general rule is that

> *"you need 300 credits for an honours degree"*

but maths is an exception

> *"the rule is only 280".*

Of these at least 80 must be at final year level, and at least 180 at second and final year level. Students are able to enter the second year with 80 credits which is

> *"quite a difficult decision for us"*

and such students tend to do less well

> *"roughly 1/3 graduate with 2ii degrees, 1/6 with 3rd class degree, and half don't make it".*

These figures illustrate the dilemma faced in striving for an equitable balance. For the sake of those who more or less recover from a poor start it is worth allowing some flexibility. At the same time this means that some students who might have been better leaving after year one may continue for a couple more of years and then fail.

At another institution students take

> *" eight modules in the first academic year, and they have to pass six in order to progress to the second year".*

This scheme continues over the three years and

> *"degree classification now is ....based on averages over all twenty-four courses".*

This is weighted however so that modules taken in the first, second and third years count 10%, 30% and 60% respectively towards the final degree mark and students must pass at least 18 in total to obtain a degree. Students have two opportunities to take resits, either to progress or, if already qualified to progress, to improve their marks but in either case these are capped at 40%. Although framed in rather a different way, the effect of this scheme is similar to that of the first institution, allowing flexibility for students to progress while carrying some failures, and not requiring all modules to be passed to obtain a degree. The proportion of first year modules needed to progress is slightly higher however and there is a greater incentive to resit first year modules since these count in a small way towards the final degree mark.

At a third institution the regulations for the degree award have rather less flexibility. Students take six modules in each year and in order to obtain an honours degree all except one must be passed. The remaining module can be awarded a compensated pass if the mark is 35% or above. One resit opportunity for each module, capped at 40%, is allowed during the summer resit period. If students fail this then they are allowed to re-register for a module (which has financial implications) and effectively do the entire module again with the module mark capped at 40%. Flexibility comes however from the possibility of progression while "trailing" up to two modules, of which one may be with full attendance. Of course, re-attending a module from the previous year sometimes has timetabling implications because of potential clashes with modules from the current year. It is also possible for students to take a "slow diet" and spread their academic study over a longer period to help cope with the pre-requisite structure and added burden of re-registered modules. For each student two final marks are calculated, one being just the average of the final year modules, and the other a weighted average, 25% for the second year and 75% for the final year. The degree classification is then based on the better of these two marks

Taken together the schemes above offer two approaches to flexibility, the first one by not insisting that all modules are passed for the award of an honours degree and the second one by allowing trailing modules and varied study patterns. For an entrant with good entry qualifications and high motivation there isn't in practice a lot of difference between the schemes. They would pass all modules without any progression difficulties and finish with a good degree. A student who is late developing, or who finds motivation halfway through the course, would be slightly advantaged by those schemes which don't include first year marks. They would also be advantaged by the opportunity in the third scheme of having the degree classification rest only on final year marks, this being particularly useful where students become highly motivated by an industrial placement year. Then comes one of the difficulties of comparing across institutions - is a student who finishes well comparable with one who has performed consistently well across at least years 2 and 3? Does exit acceleration compensate for lack of second year consistency? At the other end of the spectrum, how far should a scheme go in giving opportunities for failing students to recover their position and continue? This is not mainly a question of standards. A student who eventually manages to satisfy any of the above sets of regulations is worthy of a degree of some sort, and they will not be branded as high flying mathematicians. The difficulty is rather the one of wasting a failing student's time by allowing them to continue too long. Allowing complete flexibility in following a slow diet for example runs the risk of a student gradually failing over a period of years rather than being encouraged to find an alternative more profitable track.

In many institutions there is a high degree of standardisation of assessment schemes across faculties, which means that colleagues in mathematics departments often have limited ability to change schemes in a way they might feel desirable. Change may mean finding common cause with colleagues from other subject areas and gradually chipping away at the system - although sometimes this can feel like trying to turn an oil tanker from a position which has no communication with the bridge.

As well as the nature of the assessment scheme an important issue in comparing between institutions is what is being assessed and at what level. Students come out of different types of maths degrees with

> *"a rather different skill set…"*

A colleague having familiarity with masters students noted that they had found students from courses with a more practical and technological bias

> *"motivated, independent, good at project work, ….. able to show initiative"*

even though students from more theoretical courses may have been

> *"taught more pure Mathematics".*

This illustrates that there is more than one way to achieve a high standard, although at this stage students are probably still demonstrating potential to become excellent mathematicians rather than having reached that status. In looking for the highest standards, perhaps a first degree should be regarded as a place to identify excellent mathematicians in the making and to take them a significant way along that road. Potential high fliers from different institutions may bring different attributes to postgraduate education and will need to further their development in different ways. With this in mind then perhaps the comparison between institutions becomes that of comparing how well the best students are identified and motivated while recognising that their undergraduate experience may vary substantially. A number of institutions run an MMath in parallel with a BSc. Where this is possible then this provides an explicit way of identifying the most able - either from the start or by transfer from the BSc on the basis of proven ability during the course.

4. Deadlines, missing work and extenuating circumstances.

In addition to an assessment scheme itself, the other important part of the regulatory framework is the ability to deal in a measured and just way with students who are in difficulties, whether these difficulties stem from lack of engagement or extenuating circumstances (ECs).

Dealing with large numbers, it becomes unmanageable if much leeway is given with coursework hand-in. In two of the institutions we spoke to if work is not handed in on time then, at least officially, it scores zero

> *"It's very tight, very tight, ... if course work is late it doesn't get marked".*

There was, however, evidence of a little more flexibility being applied unofficially at a local level. Where the system doesn't allow for extension of deadlines then sometimes it is done

> *"informally, and not supposed to be done at all".*

This perhaps shows that staff felt that the university regulations they are asked to operate under are a little too rigid.

There is also flexibility in that sometimes in modules with frequent coursework there are one or two spare courseworks so that

> *"they drop their weakest course work "*

and the marks are computed from the remainder. A third institution did retain some room for manoeuvre with deadlines *"they get one day's grace, they lose a mark if they hand it in a couple of days late without any good reason".*

As numbers on Mathematics degrees have increased there has been a trend though for deadlines to become harder. One of the institutions now not allowing any late hand in used to operate a sliding scale of decreasing marks up to a week late.

Extenuating circumstances also tend to be dealt with quite formally, tracked by supporting documentation

"we've got web forms"

and considered at either departmental or faculty level. This is partly again a result of increasing numbers but also for tracking of appeals. One colleague spoke of a case where a local decision not to accept some supporting documentation was

"overruled by the central administration, just for legal reasons".

There was a feeling at another institution that a faculty based panel could be too remote from the students that they were considering, which sometimes led to genuine ECs being rejected. Once ECs are accepted approaches vary between institutions. At one institution, if EC's are accepted for a piece of coursework

"we replace this coursework mark by the average of the remaining coursework"

and if the circumstances result in the student missing a test then

"the exam mark counts for the test".

At another institution however the normal rule is that if a student misses work or a test due to ECs then they still have to do them but over a longer period of time. There are advantages and disadvantages to both these approaches. If a student still has to complete missing coursework or tests then it can be a burden when they are also trying to catch up with a range of other things. It can also be difficult to count these for credit when model solutions may have been issued, a problem more prevalent in maths and other science/engineering based subjects where some assignments have a tightly defined "right" answer. On the other hand if they don't complete missing assignments they may be insufficiently prepared for a later part of the course. Flexibility in university regulations allowing some local decision on the combination of tasks given to a student in this position is clearly desirable. Approaches to examinations after ECs have been accepted seem more uniform, with students being allowed to take a first sit alongside referred students, but with no capping of marks.

As well as non-handing in of coursework, the most of obvious indicator of lack of engagement is poor attendance. Universities are coming round to the conclusion that attendance needs to be monitored and poor attenders followed up quickly. There are perhaps however some symptoms of reluctance:

"we don't have a nice automated system for doing it" .

Picking up non-attending students quickly and talking to them can sometimes help to turn things round

"almost invariably, there's some underlying problem".

It is however resource intensive

"it relies on .. the Administrator then having the time to chase up"

and if it is not done quickly then it loses its point

"by the time you get into about the last, say, third of term, it's kind of hard to really do very much about it."

Ultimately it is not a kindness to a student heading for failure to let them continue on a course, and so mechanisms are needed by which students' registrations can be terminated. At one institution such a mechanism was in place for the first and second year students. This is based on coursework, the criterion being

"large numbers of non submissions.... more than a third proportion of total number of marks"

such people were sent warnings and asked for an explanation and eventually a small minority of them (in the order of 10%) recommended for de-registration. This contrasts with another institution where students normally only withdraw as a result of exam board decisions at the end of the year, although their attendance and coursework performance will have been monitored and commented on during the year. On an optimistic note, cases where students have failed on one course and then, perhaps after a period of reflection, have started again elsewhere and been successful are not uncommon and indeed we can think of several in the last few years. No doubt part of this is a process of maturing and finding greater motivation, but there is also an element that a student's style of work and method of study may be better suited to one assessment scheme than another.

5. Summary

While identifying the very best potential research mathematicians and those with excellent skill sets for employment, a good assessment scheme must serve the needs of all. This means allowing sufficient flexibility for late developers to demonstrate their potential and for initially poor performers with a realistic chance of recovery to get back on track.

Some overall schemes provide flexibility by not requiring all modules to be passed while other schemes allow students to re-register for modules and stretch out study over a longer period of time. In both cases however there is a balance to be struck between giving opportunities to recover and allowing failing students to continue too long.

Diagnostic assessment on arrival is common and helps in planning extra support. In one institution such assessment defines a core of essential mathematics in which students must prove competence, alongside other first year modules, before progression to the second year.

Frequent small coursework tasks in the first semester can also be used in a supportive way, together with attendance monitoring, in locating and helping students having early problems, very often rooted in non-academic factors.

The transition from first to second year studies is often a difficult one and needs to be taken account of in assessment scheme design. First year assessment must be rigorous enough to ensure that students are prepared for second year study, and second year assessment must be realistic in its expectations.

Timing of examinations, semesterised or annual, can influence performance but there seemed to be a staff consensus on the view that annual exams facilitate greater coherence across the curriculum.

Schemes for calculating final degree classifications are varied, particularly with respect to weighting given to the first, second and third years. At least one scheme allows the selection of the better of two alternative calculations so that classification may be based only on final year performance with consequent advantage for late developers. Other schemes include a higher proportion of second and sometimes first year marks, rewarding consistency across the years.

While an assessment scheme should satisfy the requirements of the institution and student population for which it is designed, it is also important to know how it relates to those of other institutions. Mathematics courses vary widely in their approach and it is unrealistic to expect that assessment at each institution measures exactly the same set of attributes in a student. What should be possible though is to recognise what each of these attributes brings to either postgraduate education or the employment market, and hence to compare students in terms of their potential to become first class employees and/ or excellent research mathematicians.

6. Good Ideas

Amongst the many features of assessment that arose in our discussions, it seems worth picking out some that are particularly relevant in helping all students to develop as much as possible while being able to clearly identify the best:

- Extended diagnostic testing. Multiple opportunities through the first year to resit a test on mathematical essentials with appropriate support and a requirement that it is passed before the second year. This at least ensures that students are secure in the fundamentals before facing the sometimes difficult progression to the second year.
- Flexibility in a frequent coursework scheme so that the worst courseworks do not count. This allows students a little spare capacity in coursework without having to invoke the heavy machinery of extenuating circumstances.
- Attendance tracking. When this is combined with information from a frequent coursework marks profile and an efficient system for following up then students having problems can be picked up early and supported.
- An overall system which includes two alternative calculations for degree classification based on either just the final year marks or the final year marks combined with other years in some proportion. This rewards consistency, but also allows for the possibility of a student "blossoming" in the final year - possibly after a year on industrial placement.
- Recognition of the different skill sets from different types of maths degree and the varied contributions these can make to employment or postgraduate education. Students can then be compared across institutions on their overall potential.

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6.3 *Automating the marking of core calculus and algebra: eight years on*

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Abstract

In 2002 we implemented a computer aided assessment system to automate the more routine questions in our core calculus and algebra course. This system is still in use after eight years and more than a thousand students have made use of it. In this respect it has been a quiet success story, providing rapid feedback to large groups of students and a time and cost saving to staff. This case study is a reflection on our experiences.

Background

In early 2000 at the University of Birmingham, the Learning and Teaching Support Network held a day meeting to discuss computer aided assessment (CAA). At this meeting Norbert Van den Bergh and Theodore Kolokolnikov of the University of Gent, Belgium, demonstrated their computer aided assessment system AiM, based on the computer algebra system (CAS) Maple. Within the context of a `subject' and `quiz', the student is asked a (randomly generated) question. Each student enters their mathematical expression as an answer using Maple's syntax and the CAS seeks to establish various mathematical properties relevant to the question. On the basis of these properties, AiM can generate outcomes including feedback, a numerical mark and a "note" for later statistical evaluation. Which random version is given, all attempts and all associated outcomes are stored by the system for later use.

Derk Hermans set up and used AiM within his third year course within the School of Mathematics at the University of Birmingham. Then, during 2001, we made a decision to implement computer aided assessment within our first year core calculus and algebra course. This is a traditional methods course, which includes single variable calculus and linear algebra. Assessed formative problem sheets were issued to students weekly and marked by postgraduate teaching assistants. This was costly and is arguably not the best use of postgraduates' time. We also wanted to provide more feedback to students in a timely manner without increasing staff costs.

These paper-based problem sheets were already divided into three sections. Section A contained short answer questions for which students had usually been given direct instruction during lectures. Section B contained more extended problems and Section C some more challenging material. We decided to automate Section A questions as far as was possible within the limits of the technology. Section B, and questions we could not automate, remained as paper-based assessments.

Implementation

Once the decision to proceed had been taken, practical implementation had three phases.

1. Install the software.
2. Encode the questions and assessment criteria in CAA format.
3. Implement CAA as part of the normal weekly teaching cycle.

Dr Hermans installed and used the original version of AiM, but the technology moved on and we made use of AiM 2.0, written by Neil Strickland, of the University of Sheffield [1]. A small grant enabled us to purchase a dedicated server (still in use for this purpose) and to pay postgraduate students to help with the process of encoding our existing questions.

Barriers and enablers

We are fortunate to have a dedicated member of support staff and so there were very few technical barriers to setting up the server itself and installing the software. We also have few institutional barriers to installing a server on the campus network. Having staff who would take responsibility for the server within the School avoided the need to ask central computer staff to take on this work.

To reduce the twin problems of impersonation and plagiarism, we wanted to include random versions within the questions. The use of a CAS enables structured random objects to be created and manipulated before being included as part of the question. Steps in worked solutions can also be easily generated. We asked our postgraduate students to do this work, but in fact they needed quite a lot of guidance. There are some very interesting mathematical problems involved in reverse engineering the mathematics to create feasible questions: problems we might more profitably pass on as part of undergraduates' assessment! There are pedagogic decisions to ensure all the cases are seen by an individual student and some thought is needed to maintain a uniform level of difficulty. Initially at least, and without sufficient guidance from us, our postgraduates were sometimes too enthusiastic.

The safest way to randomly generate questions is to ensure invariance of the worked solution. Implicit in the worked solution are decisions about the level of detail required for the particular student group. If you need a different worked solution, you probably have a different question. This may be desirable, but then randomization is probably best achieved by selecting from a list of question templates, rather than randomly generating versions within a single template. In AiM it is possible to choose a question by selecting from a list of templates and then randomly generate a question from this template, fulfilling both needs.

AiM requires a student to use Maple's strict linear syntax to enter their expression. This is the largest barrier from their point of view. However, as mathematics graduates we decided they really needed to learn this syntax. They will probably be working with mathematical machines, so while this is a barrier it is one they simply have to pass. With support and guidance, students do learn the required syntax.

Evidence of success (impact)

The most important evidence of our success is the eight years of use. Over a thousand students have used AiM during that time. The fact this causes so few problems and so little fuss is remarkable. Of course, on occasion the network failed and this is frustrating for students and embarrassing for staff. Our problem sheets do have a small summative component, and we have used AiM for some high-stakes summative class tests. Basically it has proved most useful as a formative tool. It has been remarkably stable, seeing the birth and death of a number of institutional virtual learning environments during that time, and it remains a more sophisticated tool for assessing mathematics than anything centrally provided.

Our students broadly agree when asked.

> *"I like the fact that feedback is immediate, but I do not like the fact that if I get an answer wrong I do not know where in my working I have made the error."*

> *"I like the way that you are given credit if your answer is partially correct and also given guidance on achieving the full mark for that question."*

Many of our students understand what we are trying to achieve in providing such randomly generated practice in a formative mode.

> *"The questions are of the same style and want the same things but they are subtly different which means you can talk to a friend about a certain question but they cannot do it for you. You have to work it all out for yourself which is good."*

Initially we simply replicated existing paper based assessment as CAA. But we have gone further to examine what is possible in this new environment. This includes the use of more open-ended questions, such as that shown in Figure 1, which ask for an example of a mathematical object. In many cases the CAS can establish any properties and provide feedback. These questions are rarely set in conventional situations probably because they would be so time consuming to mark by hand for large groups, see [2] and [3].

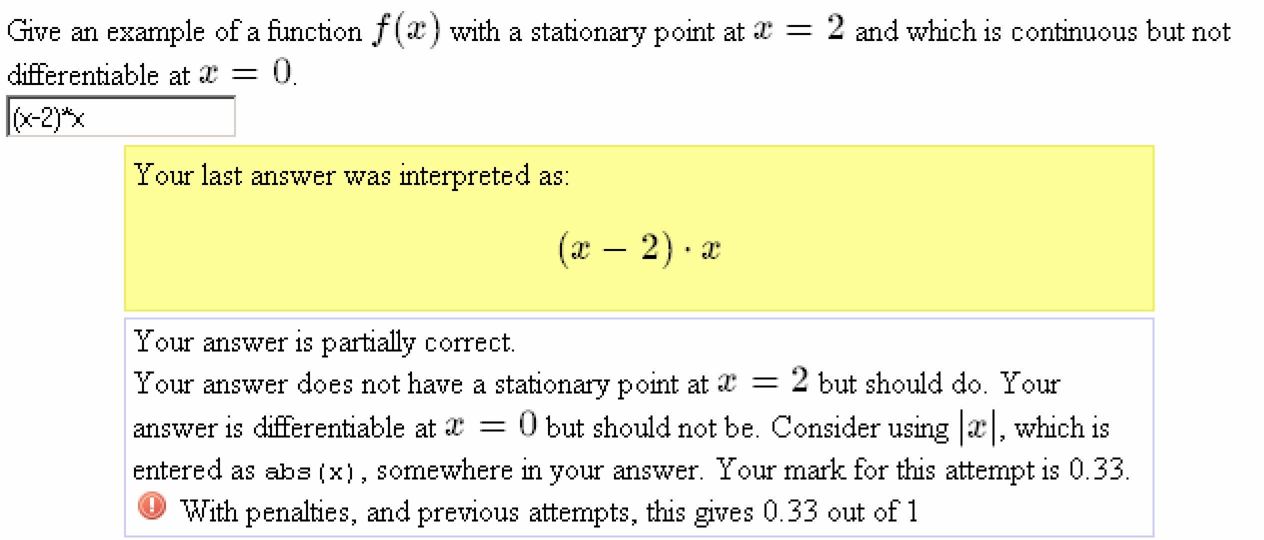

Figure 1:
More open ended CAA questions

Actually, CAA has not been used widely in other courses. After the first year core course work becomes more difficult to assess automatically, with a significant component of proof. There is, however, undoubtedly an “innovator effect” with only a relatively small number of staff showing an interest in CAA. Of course, CAA is not going to solve all our problems. Assessment of extended projects, history essays and similar work will probably always require an expert. To concede that a tool does not do everything is quite different from saying it does nothing useful. We have been somewhat conservative in the extent to which CAA could be used, but as a School there is a tangible cost saving. During that time, our numbers of undergraduate students has risen significantly and the prospect of going back to paper-based assessments is not realistic.

Beyond the School, we took part in a collaboration between a number of Universities who at that time used AiM. This was led by Gustav Delius at the University of York who set up and ran a JISC funded project Serving mathematics in a distributed e-learning environment. AiM is, after almost ten years, creaking at the seams a little. Technology moves so quickly that it is difficult to keep up. The AiM software itself is not currently maintained and for various reasons is not likely to be updated. However, the experience of using AiM in teaching has led to the development of a potential replacement, STACK (http://www.stack.bham.ac.uk), see [4]. We are currently converting our older AiM questions into this format and using STACK in the current (2009-2010) teaching session.

Recommendations

In my view there are two important strands to mathematical activity.

1. The use of routine techniques.
2. Problem solving.

We argue these strands are inseparable: problems of a particular kind can become routine and genuine problem solving may be replaced by memory or research (with a small “r”, i.e. looking up the answer). Without sufficient practice, recognition is impossible and all mathematical questions become problem solving, which is inefficient and causes difficulties in recording and communicating mathematics. But, what is the point of simply being good at technique, if we don’t apply these techniques to solve problems?

CAA is most helpful for practicing and assessing answers to routine problems. This is the use to which we put AiM. Problem solving, writing proofs in real analysis and project work remain as traditional written work. There are a variety of CAA systems, commercial and free, technically simple and those which make use of CAS. There are special systems for specific topics and general quiz platforms such as AiM and STACK. If you are considering setting up CAA I would make the following points and recommendations

- Get institutional support and funds to help.
- Payback will come in year 3. The first year is a lot of work, even if the questions are already written. In year 2 you can polish by adding better random versions, fuller feedback and complete solutions. In year 3 the materials are more stable.
- Be conservative initially. Setting a high stakes test (such as a diagnostic quiz to the whole first year in week 1) is going to strain the network and CAA server. This is asking for trouble when using a system for the first time.
- Think about what CAA is best for - it certainly isn’t everything. But then no form of assessment, (exams, projects, exercise sheets) will work for all topics.

It is easy to raise objections: CAA can’t do this, and won’t do that. It is just as easy to raise such objections for any assessment format. For example, did we ever really want `follow through marking’ anyway? This is a device used in paper-based assessment to reward what students have done. However, with immediate feedback a student can start to check their own work and hopefully track down any errors for themselves. In this way CAA might be used to encourage students to take responsibility for their own work. It is a tool, the question is how should we use it?

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7.0 Curriculum content and course design

7.1 *Some thoughts on curriculum content*

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1 Introduction

Despite our work within the More Maths Grads (MMG) project being labelled the 'Higher Education (HE) Curriculum Theme' we have said relatively little about what our curricula should contain.

We have various reasons for this. For one thing our brief took a catholic view of what constituted 'curriculum' and was certainly not focussed on the idea of what should be taught on our courses. For another, we take the view, wholeheartedly supporting what is explicit in the Maths, Stats and OR (MSOR) Benchmark statement [1], that mathematics courses can and should adopt very different approaches.

That said, our work in a number of areas has prompted some thoughts on our curriculum development, which it seems appropriate now to share. We do so in the spirit of trying to provoke thoughtful reflection on our current practice, rather than claiming that the ideas presented here are the only way to proceed.

2 An outrageous proposition

In this paper, we invite you to consider what may appear to be an outrageous proposition, namely that we should cut, say, one-third of our curriculum content from our courses.

At this point, let us define – with severe reservations – what we mean by 'content' in this context. By this we mean the list of mathematical topics which, at a grand scale might be the titles of individual modules ("Linear Algebra", say) and which close up form the syllabi of individual modules ("Row operations", "Hermite form", etc). Our reservations about this term are that it embodies and creates a wrong impression in both staff and students, that the 'content' of a maths curriculum is only the list of mathematical topics, rather than recognising all the other things which a degree might contain, However, this usage is common, and we struggle to find a better term, so for now we will use it.

Secondly, we should admit that 'one-third' is somewhat arbitrary; our point is to propose a cut which is both drastic and, for many of us, uncomfortable.

Having made this proposition, we may have provoked not thoughtful reflection but rather a more emotional response, perhaps accompanied by throwing aside this paper. But if the reader has made it this far, allow us to consider what the benefits (and disadvantages) of such a proposal might be.

3 Some background thinking

Let us start by asking: what qualities should a good mathematical graduate have?

These must include a combination of knowledge, understanding, skills, attitudes, ways of thinking, and styles of behaviour which take in mathematical, general academic, professional and personal qualities. The MSOR Subject Benchmark Statement [1], to which we shall return later, identifies more precisely the particular qualities which are required or desirable in a mathematics graduate, and recognises that the extent to which our graduates should develop these different attributes will vary between different courses. The extent to which mathematics staff should be involved in the development of the full range of skills is a subject of much debate. Some may argue, for example, that developing personal and professional qualities is not our job. We put forward a case for why it should be our job in [2] but – quite rightly – different departments will make different decisions in this respect. In this article we wish to consider in particular how our curriculum develops explicitly mathematical qualities, and we assume that there is little dissent that academic staff should have some involvement in this!

What we suggest here is that the key qualities associated with a good mathematician, at any level from school to professional research mathematicians, are not primarily related to subject *content*.

This last statement warrants some closer inspection.

Firstly, we are not suggesting that mathematical thinking can be developed in a content-free zone; rather that developing mathematical thinking is not tied to any *specific* mathematical content, or to a particular quantity of mathematical content.

Consider for a moment yourself and your colleagues; do you all know the *same* mathematical subjects? Almost certainly you are expert in some and ignorant in others, but you are all mathematicians. Your status as a mathematician is not defined by the *content* you know. Perhaps you might respond by saying that there is some content that you all know, but this is mainly a product of having had similar educational experiences, not an *absolute given* of the subject.

Alternatively, try, in no more than say 100 words, to describe the essential characteristics of a good mathematician (don't restrict yourself to a good mathematics student; rather think of outstanding mathematical researchers). Try asking your colleagues to do the same. Inevitably the answers you give or receive will vary, but we would speculate that they might include words and phrases like: analytical; logical; creative; able to think in abstract ways; independent; able to understand complex new ideas; practical; having an understanding of rigour; understanding the impact of any assumptions on final conclusions; able to construct a watertight argument; able to check and assess the validity of our own and others' arguments; formulating problems mathematically; interpreting results effectively… We do not claim that this list is exhaustive, but doubt that much of what you or your colleagues would say would be about specific content. Rather they represent mathematical *attitudes* or *ways of thinking* and *an understanding of key concepts* rather than specific *mathematical knowledge*.

Interestingly, these key qualities which are important to a research mathematician are also, by and large, qualities that employers value in mathematics graduates; employers may cite additional qualities which they require as well but these are again rarely about specific content.

Were we to press colleagues to come up with specific mathematical techniques which we must all know, the answers might include such ideas as being confident and competent with basic algebra; being able to write mathematics well, being able to create and understand graphical representations of various kinds, competence with numerical data, being able to talk about mathematics, and so on. We might call these core mathematical skills and we note again that they are not usually thought of as content of mathematics degrees. Some colleagues may extend the list into areas that we are calling here content but such a list of topics would have far less agreement than we would obtain for the key mathematical attitudes outlined earlier.

A third way of thinking about what qualities a mathematician ought to have is to consult the MSOR Subject Benchmark Statement [1]. The statement was written by a group of mathematicians from diverse institutions, following consultation with a wider cross-section from many institutions; as such we believe it broadly represents the views of a good majority of the UK mathematical community.

In terms of content, the MSOR Benchmark specifies only two topics ('basic linear algebra'' and 'basic calculus') which must be included in any mathematics degree. There are undoubtedly some amongst us who might regret this fact ("I can't imagine a proper maths degree that doesn't include number theory/numerical methods/group theory/…") but the final statement which emerged from the benchmarking exercise was in the end deliberately non-prescriptive about content. This reflects three fundamental beliefs (we would say 'truths'): that we would never reach agreement on a form of national curriculum for mathematics; that to do so would destroy the strength that our subject and students gain from courses being so diverse; and that the key qualities of a mathematician are not primarily related to *specific* content or to the *quantity* of the material covered.

The requirements it gives for degree programmes are précised in the appendix (though the reader is recommended to consult the original document) and these talk far more about core mathematical skills, attitudes and ways of thinking than about content. In the benchmark section of the statement, it says

"A graduate who has reached the typical level should be able to:

- *demonstrate a reasonable understanding of the main body of knowledge for the programme of study*
- *demonstrate a good level of skill in calculation and manipulation of the material within this body of knowledge*
- *apply a range of concepts and principles in loosely-defined contexts, showing effective judgement in the selection and application of tools and techniques*
- *develop and evaluate logical arguments*
- *demonstrate skill in abstracting the essentials of problems, formulating them mathematically and obtaining solutions by appropriate methods*
- *present arguments and conclusions effectively and accurately*
- *demonstrate appropriate general skills*
- *demonstrate the ability to work professionally with a degree of independence, seeking assistance when needed."*

We note that the only bullet points here which relate to what we reluctantly call content are the first two; the first one talks about understanding the material 'for the programme of study' and so does not specify particular content. The second is about being able to work with (calculate and manipulate) the subjects that are covered.

Finally, let us say that in our conversations with staff from the four institutions in the MMG project that – whilst we may disagree about the detail – broadly speaking these are the qualities which staff believe makes a good mathematician. Correspondingly, they are often the qualities whose absence in our students we bemoan - see [3]. Consider for example the following two quotes:

> *"What people don't really realise about a Maths Degree is that it's, it's a skills Degree and when you've got your Maths Degree if you go off into the world of work it's not really, you're not saying, "Oh look I can integrate there," [...] it's not to do with that, it's to do with, "Look I'm capable of thought on this level, I'm capable with this of dealing with this level of abstraction, I'm capable of using models and I'm capable of like applying my brain in a really strange way."*

> *"There's an awful lot of emphasis on content which, you know, you probably, probably you will realise this in Mathematics when people come to talk about.....curriculum, but they always talk about content, whereas I think in other subjects they don't, they're not so hung up on the content, they're more, they do think more about what are the skills and things that we want our students to, our students to come away with, yeah?"*

If we have convinced the reader that it is core mathematical skills, attitudes, ways of thinking and behaviour which distinguish a mathematician, and that this view is widely held amongst fellow mathematicians as responses to the benchmark suggest it is, then we can proceed to raise some awkward questions:

- Isn't it slightly strange that we design our courses (by and large) around a list of subject content rather than around a list of qualities which we want our students to develop?
- If many of us believe our curricula are overcrowded (and some staff and students certainly do), why do we persist in doing this?
- Might a focus on content, and a tendency to overcrowd the curriculum, be detrimental to our students' development?

Content-driven curricula

There are of course good reasons why we think about content when we design our courses.

For a start, the particular qualities of a mathematician are intricately linked with content; we develop our mathematical ways of thinking by engaging with the content, and we cannot understand the content fully without developing these ways of thinking. Furthermore, our previous argument is that it is not specific content (nor a given quantity of content) that defines us as mathematicians, not that we don't require any content.

It is also undeniably true that certain bodies of mathematical knowledge and understanding are more easily digested if presented as a coherent whole; thus it is inevitable that most module titles will be related primarily to content. Similarly when we think about what should be included in a module, the hierarchical nature of much mathematical knowledge will lend itself to a curriculum design which considers the particular mathematical topics so that these are covered in an appropriate order.

Such a curriculum design is also tangible, in terms of what it is we need to 'cover' in our lectures, and in how we assess, whereas some of the key qualities of a mathematician are less straightforward. Indeed the MSOR Benchmark reflects this by saying

> *"a number of subject-specific skills are to be expected of all MSOR graduates. Most of these will be formally assessed at some stage during the degree programme. However, it must be recognised that some are not necessarily susceptible to explicit assessment. Some pervade all mathematical activity and will be reflected in assessments focused on many areas of subject content."*

Whilst recognising the truth in this, we were reminded of an exercise (for many, forced on us particularly in the dark days of teaching quality assessment or subject review) when we were forced to specify for each module the desired learning outcomes, the assessment methods, and the criteria used to assess whether a student had achieved the learning outcome. The temptation for a mathematician was to say that the learning outcome was 'being able to solve a linear 1st order differential equation', the assessment would be to 'solve a 1st order linear ODE', and the criterion would be 'getting the right solution'. Perhaps as mathematicians used to dealing in absolutes in much of our work, we are particularly keen to specify things so tightly. (Perhaps it was also a reaction to an external imposition whose usefulness we questioned.)

We should also recognise that we may think in terms of content in particular because this is what is familiar to us; it is the line of least resistance.

There are, however, certain risks as well with this approach.

Firstly, do we actually test the qualities we think appropriate in a graduate mathematician, rather than raw subject content (this is particularly acute in examinations perhaps)? By focussing on specific content, there is a risk that what we actually test is, say, the ability to memorise and reproduce a theorem, or the ability to solve in an algorithmic way a particular type of problem. It could be argued that this is not something to worry about; fully getting to grips with the content we teach requires students to develop these key qualities we value; and students will not be able to pass without developing them. To some extent this is undoubtedly true, particularly perhaps for our very best students. In order to get a first class degree, demonstrating a good understanding across the whole range of our curriculum content probably does require students to have developed the qualities that we value. That said, perhaps it would help us and our students if our stated assessment criteria matched what we are really looking for.

Secondly, since our curricula are known to students, this tendency to specify content rather than core mathematical skills sends a strange message to them. Were we more explicit about the qualities we expect of them, perhaps they would focus more on developing these.

Even more importantly, perhaps we would also focus more on teaching them. This is a tricky issue, and one that may be clouded by our own atypical experience of undergraduate maths. One way or another, we *did* acquire the requisite mathematical abilities alongside the content. Our best students do the same, and we tend to hope that all of them will do so. But this is not necessarily the case (judging by staff comments and personal experience), and even if it were, there is no clear reason why we should teach the content, and leave them to pick up the skills and attitudes of a mathematician incidentally.

Finally, we wonder if a content-driven approach might in itself contribute to overcrowding of our curriculum. Because we write our curricula this way, we start perhaps to believe that every part of our current content is sacrosanct, and that it would be sacrilege to remove it (Back to “I can’t imagine a maths degree that didn’t include…”) and to believe that removing any content is ‘dumbing-down’ (we shall return to this later). Both beliefs seem to be somewhat at odds with our other attitudes about what constitutes a good mathematician.

5 Shifting the balance to a skills-and-qualities driven curriculum

In the light of these ideas, we would like to present an alternative way of thinking which may have merit: that is that in our curriculum design we should think more in terms of the qualities and skills that a student has, rather than the content that we deliver. As outlined in section 2, we expect that this would need to be combined with a drastic reduction in content.

Suppose that, rather than thinking ‘what content do we need to get through’, we thought in terms of mathematical qualities which we want to develop in our students.

Firstly, we should identify the qualities they do (and don’t) have when they arrive, being sure to deal with what they are actually like rather than what we think they should be like. Next we must identify those attributes that our students should have by the time they graduate. (The benchmark certainly provides a good starting point for identifying them.) We are not proposing that we should engage in a sterile form-filling exercise here, but rather an honest and professional evaluation of what is most important.

Having established the qualities that we want them to have, we could then consider what set of content could be used in order to best develop these qualities, and crucially, how this content is used to develop these skills, throughout their time with us, so that we are as clear about the progression of the students’ skills and qualities during their course as we are currently about the progression of their content knowledge. What is more, we should be prepared to devote our time and effort to actively teaching the things which we value.

For example, if we believe that writing mathematics correctly is important, then we should tell the students how it should be done (gradually – it’s a big topic), demonstrate the use of the concepts whilst we work on carefully chosen subject content, and allow them to practice the development of those skills as they work on the subject matter. Initially we might work on correct use of mathematical notation but this might lead naturally into a discussion of why correct use is important in helping, for example, to develop logical arguments effectively, all the while introducing suitable content for them to work on and learn alongside it. To be effective, this must also be combined with assessment and marking schemes which explicitly credit the core skills we seek. By being explicit about teaching and assessing core skills, we would also send a message to our students that these are important.

(It could be argued that some core mathematical attributes such as writing mathematics could be taught as a separate module in which new ‘content’ is not delivered, but we speculate that this creates an impression that it is an optional extra, not something which should be a part of everything we do, and that embedding it into core mathematical content makes the ideas less abstract to the student. This is another reason why even with this way of thinking, we would anticipate module titles still being related primarily to content.)

One difficulty of this approach would be ensuring that different lecturers co-operated with the overall plan, and designed their courses to accommodate and teach the skills which were appropriate to the student at that stage in their development.

If this rethinking of the way we design curricula happened without a reduction in course content, many lecturers would point out that teaching additional skills would require them to rush through the required course material, exacerbating the over-crowding of the syllabus. This is one reason why we propose that this would have to be accompanied by a reduction in course content.

This is not, however, the only reason we think a cut in content should be considered. There are more fundamental ideas about possible advantages of cutting content.

Let us consider some of the key skills we value again: for example persistence; willingness to explore and experiment; independent thought and creativity; checking the validity of our own work; searching for a deeper understanding… There are almost none of the core mathematical skills and attitudes which are enhanced by having a crowded curriculum. Quite the reverse. A crowded curriculum encourages students to adopt approaches to learning mathematics which are at odds with what we desire. Consider the following ideas:

- We want them to be fully competent with basic techniques and methods, which needs time to practice and assimilate them, but we teach them briefly in our rush to get on to the 'real' maths.
- We want students to strive for a deep understanding of the material, but we rush them because we have content to 'get through'. Deep understanding requires confidence with basic ideas and time to explore and experiment and make mistakes.
- We want them to learn from their errors, and review and revise their understanding of the content as a result of our feedback, but they are too busy with new material to worry about past mistakes.
- We want students to avoid pattern-spotting and algorithmic approaches without understanding, but our focus on content and speed drives them to consider the easiest way to answer 'that type' of exam question.
- We want them to be reflective about their learning, and be used to checking the validity of their own arguments, but lack of time means they look to us to check the validity.
- Crowded curricula encourage the kind of surface learning which we deplore in our students (and with half an eye on our weaker students, it sometimes encourages surface teaching too). Under pressure, they will focus on 'getting through', on the next test, and on the next bit of content, rather than on their learning.

We would make a further point about this, in relation especially to the issue of transition to university study. It has become almost axiomatic that students arriving at university are 'ill-prepared' for university mathematics; certainly they lack skills and qualities which we believe are essential to a mathematician. If we treat the quantity of content as sacrosanct but that our students have less well developed skills when they arrive than we did at a similar stage, then there are two effects. Firstly we fall into the belief that there is certain essential development which we must rush through at the start of the course (thereby increasing student workloads rather than easing the transition). Secondly our courses will contain even more material than they used to, which far from allowing the students to develop the key qualities of a mathematician might instead exacerbate a situation whereby some focus primarily on 'getting through'.

A scheme which explicitly seeks to develop the key skills and qualities of a mathematician, particularly in the early part of the course, might have one further advantage which would affect the students' future performance with the content we do include. That is that these key qualities are not only essential in themselves, but also enable us to engage fully with new material we meet. Thus we would argue that time spent explicitly teaching, learning and assessing key mathematical qualities enables the students more fully to engage with content which is presented later.

6 'Dumbing-down'

Would such a move result in a lowering of standards? The answer to this question might seem straightforward to some, but we do not believe that it is quite as easy as it might at first appear.

For a start, we are not really suggesting that we teach less; rather that we teach different things. If a student were to emerge from a mathematics degree knowing less mathematical content, but with that content understood more deeply and with their having more finely honed mathematical attitudes and ways of thinking, are they are more or less well qualified a mathematician than one who knows lots of content, but not very well and with less well developed mathematical qualities? We return to the arguments given in section 3 and ask the reader: what are the essential characteristics of a good mathematician?

Secondly, there is a lingering question over whether the current standard of mathematics degrees is appropriate. Our subject has the reputation that it is hard. This is a double-edged sword: on the one hand the difficulty is one reason why mathematics degrees are seen as prestigious and valued; on the other it is also one reason why we have too few mathematics graduates, and why some of those who do graduate are delighted to finally see the back of the subject. Colleagues will vary in their attitudes to this - some we have spoken to have expressed the view that it *should* be hard. But we wonder at a situation where students are sometimes discouraged from doing maths A level unless they did exceptionally well at GCSE, and discouraged from doing a degree unless they got a grade A at A level, and then can struggle to gain a degree despite working hard during it. Would this be true in other subjects? Perhaps (whisper it quietly) our degrees are *too* hard!

Another obvious criticism of cutting content would relate to the very best students who are destined to go on to postgraduate work. Might they not need the content which was developed during undergraduate study in order to proceed?

This argument certainly carries some weight, but there are a number of responses to it: the first is that it would be odd (but perhaps not unusual) to design our degrees especially around the small minority who follow this route. Might we not be better designing our courses around the majority and then thinking about how to prepare the minority for postgraduate work?

The second is that we are not proposing that students should not study any topics in depth; some level of depth in the course would still be a requirement. However, it is certainly true that if students had never met certain topics during undergraduate study, they would be unlikely to choose them for further study, and if they had covered other topics in less depth, they may be ill-prepared to start their postgraduate study.

The former point concerning ignorance of possible fields of study is probably the most potentially damaging; even with, say, seminars introducing topics to potential postgraduate students, there is a risk here.

To the latter point – regarding being ill-prepared – there are two thoughts: if students have better developed their core mathematical qualities, they might actually be *better* equipped to undertake further study, even if the particular subject content has still to be learned. And surely one characteristic of a good mathematician is that we have the ability to learn new mathematical topics as the need arises? A future PhD student, with their mathematical skills, will surely be able to do this.

7 Conclusions

Our argument here could be summarised as this: the essential characteristics of a good mathematician are neither related to any specific content, nor to any particular quantity of content, but rather to certain attitudes and behaviours that we bring to the content we work with. Focussing on content obscures this, both in our minds and our students, and seems to lead us inexorably to over-crowded curricula. This has the unintended consequences of making it harder for our students to develop the attitudes and behaviour that we (mostly) agree are essential. Cutting a substantial proportion of our current content might allow our students to become better mathematicians.

Since we have been discussing the qualities of a good mathematician during this article, let us return to our own roots at the end by saying that we are well aware that, by mathematical standards, the argument we have presented here is not watertight. If our theorem was 'mathematics degrees would be better with less content', we cannot claim to have proved it. But as we all know, an inability to construct a proof does not mean the theorem is false.

As mathematicians, since we can't prove our ideas, we readily acknowledge our own uncertainty about them. Certainly the original 'outrageous proposition' of cutting one-third of our content is arbitrary. However, we hope here to have provided a convincing enough argument to persuade our colleagues that this central idea deserves thoughtful consideration.

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Appendix: Summary of the 'Knowledge, understanding and skills' which should be developed in a MSOR degree programme

Paraphrased from [1]; readers are strongly advised to refer to the original document for a fuller description. Numbers refer to paragraphs in the original document.

Subject-specific knowledge and understanding

General principles

3.8 Knowledge and understanding 'appropriate to their main field of study'
Some results 'from a range of major areas'
'At least one major area of application'

Methods and techniques

3.9 Common ground: basic calculus and basic linear algebra
Other methods 'according to the requirements of the programme'

Areas of mathematics

3.12 In 'theory based' programmes, knowledge and understanding from a range of major areas to support understanding of mathematical methods and techniques.

3.13 In 'practice-based' programmes, knowledge of results from a range of areas to support 'understanding of models and how and when they can be applied, rather than …providing a deep understanding of the mathematical derivation'

Mathematical thinking and logical processes

3.14 Understanding of importance of assumptions and 'consequences of their violation'. Distinctions between validity of assumptions and arguments. Appreciation of generalisation and abstraction. Possible emphases include logical argument and deductive reasoning or analytical approaches to problem solving

3.15 Such thinking to underpin other activities such as axiomatic approaches to pure maths or general role of modelling

Numerical mathematics and mathematical computing

3.16 Knowledge and understanding of 'processes and pitfalls of' approximation

3.17 For many programmes: some knowledge and understanding of computing in maths

Modelling

3.18 Knowledge and understanding of modelling from at least one application area

3.19 For many programmes, knowledge and understanding of a range of techniques, limitations, need for validation and revision of models; using models to solve underlying problems; interpreting results.

Depth of study

3.20 'Particular areas' and 'some topics', dependent on the particular degree programme, to be studied in depth.

Subject-specific skills

3.21 A broad range of activities, with skills to a 'sufficiently high level to be used after graduating' whether professional or higher academic study

3.22 'A number of subject-specific skills are to be expected of all MSOR graduates' which may be formally assessed but may not be 'susceptible to explicit assessment. Some pervade all mathemaitcal activity'

3.23 Knowledge of key mathematical concepts and topics; being able to 'comprehend problems, abstract the essentials of problems and formulate them mathematically'; understand how mathematics might provide only a partial solution; 'select and apply appropriate' processes; construct loical arguments; clear identification of assumptions and conclusions; where appropriate use IT for mathematical process and research; present arguments and conclusions with accuracy and clarity.

3.24 Subject specific skills related to particular branches of MSOR. 'An exhaustive list of such skills will not be helpful'.

General skills

3.25 All MSOR subjects are 'essentially problem-solving disciplines'. A 'general ethos of numeracy and of analytical approaches to problem solving'. Application of theory from gained in one area to others.

3.26 There are some general skills 'not susceptible to explicit assessment'

3.27 General study skills: independent learning; use of a variety of media; independent working; patience; persistence; time management; organisation; adaptability (especially addressing new problems); transfering knowledge to new contexts; assess problems logically, and approach them analytically; highly numerate; general IT skills; research skills including referencing; communication; team work; contribution to discussions; writing skills; communicate results. 'Where appropriate' knowledge of ethical issues and sensitivity regarding personal data.

7.2 *"Employability" skills in mathematical courses*

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A degree in a mathematical subject is special not only because it involves studying mathematical sciences, but also because it develops certain valuable skills, such as logical and abstract thinking, and an analytical approach to problem solving. But what other more generic skills might, say, future employers or colleagues expect or hope for in our graduates?

As we work on the More Maths Grads HE curriculum theme, one task we are given is to "ensure that the requirements of employers are considered". Indeed the upcoming STEM project has the related aim of "more, and more employable graduates". This is an issue which is not going away, and it raises questions about what a university education is for.

We choose in this present instance to interpret this aspect of our task as to "ensure that the employability of our graduates is considered". We have gathered a variety of information through questionnaire, individual and group interviews, from both staff and students at four diverse institutions (including our own), and we have exploited other sources, about the issue of skills, and we report below upon some of what we are finding, in the hope of provoking discussion and debate.

Which skills and why?

First let us ask whether our data supports why we should consider the matter of graduate employability. Our questionnaire was completed by 223 mathematical sciences students across diverse universities during their first year induction week. In answering a question concerning why they chose to apply to university, 93% rated the statement "I need a degree to get a good job" as 'very' or 'quite important', with a fairly uniform response across the institutions. Our students may (or in some cases may not!) love mathematics, but clearly they see a degree as providing them with an advantage when it comes to getting well-paid work.

The importance of employability is confirmed more widely when we look at graduate destinations, for instance as presented on the Prospects website [1]. 61% of 2007 Mathematics graduates who provided information were in employment or combining employment with study in early 2008. Incidentally, of those in employment, 40% were working in business and finance, with only 2.1% in engineering, or scientific research, analysis and development. Many of the remainder were in generic roles under headings such as managerial, clerical and secretarial jobs. Where do our preoccupations, whether about research, or about what topics and content to include in our curricula, stand in the light of these data?

As for the national context and implications of this, a good overview is to be found in Stephen Hibberd and Michael Grove's MSOR Connections article [2]. Employers have repeatedly said that they not only value our graduates' specialist skills, but would also look for development of a range of generic skills, what might be called employability skills, including amongst others written and oral communication, team working, and IT skills.

Indeed the subject benchmark statement for mathematics, statistics and operational research [3] in paragraph 3.27 acknowledges the importance of developing these skills, although it does also acknowledge that some programmes will develop them more than others. In any case though, given the benchmark statement, there is recognition that generic skills development is a concern to be addressed in university degrees: it cannot be left only to schools or to employers themselves, as we would surely like to think that our graduates are literate and articulate. Not all feel comfortable with this:

> *"it's sort of sad that we have to make up for all education in society's ills. We are not allowed to drop standards of course…"*

In the semi-structured interviews we conducted – a total of 35 with a variety of staff and students from the four institutions – the issue of generic skills did not feature consistently across the institutions, and this fact is worthy of mention. It may be that more would have been said if we had specifically guided the conversations that way, but in the end the responses varied from one institution to another, with considerably more emphasis placed upon the issue in the post-92 than in the pre-92 institutions.

What do students say about skills?

We asked the 223 new first year students who took part in our questionnaire about which skills they expected to develop during their course, and which they expected to be important to them in their future life, whether in work or elsewhere. A selection of relevant results appears in Table 1.

Skill area	Expected to develop during course a lot or quite a lot	Expected to be very or quite important in future life
Logical thinking	98.2%	99%
Analytical approaches to working	96%	98%
Applying mathematics to real world problems	93%	95%
Thinking in abstract ways	91%	81%
Written communication	57%	86%
Oral communication	67%	92%
Making presentations	57%	82%

Table 1

Clearly even though at this early stage students are recognising the potential importance of generic skills, it is not surprising that expectations match better for skills which are recognisably mathematical, than for more general skills. In many cases students do not expect skills to feature at all:

> *"I didn't expect to have something like professional academic skills either - that's not really maths at all."*

In fact it is not uncommon for students to object:

> *"I took [Maths] obviously 'cos I enjoyed it at school and I don't really like dealing with words";*

although they sometimes appreciate after the event being forced to address their skills. One tutor reports of a student who complained about a report writing exercise:

> *"he'd learned an enormous amount and it was a very good bit of assessment in his opinion."*

What do staff say about skills?

There are interesting developments and thinking taking place in our various institutions both with mathematical and generic skills development. In all cases there is of course an emphasis on developing mathematical skills. There is some interesting thinking going on about the idea that what a mathematics degree should really be about is skills and behaviours rather than particular content:

> *"... in Mathematics when people come to talk about…curriculum… they always talk about content, whereas I think in other subjects they don't, they're not so hung up on the content… they do think more about what are the skills and things that we want our students to… come away with"*

> *"I mean what people don't really realise about a Maths degree is that… it's a skills degree and when you've got your Maths degree if you go off into the world of work… you're not saying, 'Oh look I can integrate these'… it's to do with, "Look I'm capable of thought on this level, I'm capable with this of dealing with this level of abstraction, I'm capable of using models and I'm capable of like applying my brain in a really strange way and like problem solving."*

This prompts us to present a light-hearted caricature of the design of mathematics courses, with which we invite readers to take issue. We overcrowd our curriculum, as we all have pet topics which must be in so that we can feed our research programme. This is to the detriment of the majority of students who are not going to be research mathematicians, and the need to cover so much ground does not give most of our students the space to work on and develop those good mathematical behaviours and skills that we say we expect them to have upon graduation. These ideas are discussed more fully in [4].

All this is before we turn to generic or employability skills, which we do now! In two of our institutions there is a well-developed strategy for generic skills development, more of which below.

In the other cases it is less well developed. In a discussion about project work and writing skills and "that type of thing", one response was:

> *"Very important, we do almost none of that and… we should. I mean, we can't… do everything."*

In another discussion:

> *"...you're teaching... the subject for its own sake, and for the 2nd and 3rd year courses, to support those, more than thinking 'what skills will this person need in their job in 10 years time'."*

One implicit thought here is that there are choices to be made about what topics and activities we put in front of our students, and we need to be explicit about the criteria by which we are making our judgements. There is of course a balance to be struck, and a tension between on the one hand staff priorities, interests and preoccupations under pressures such as the RAE, and on the other hand student concerns and expectations with regard to being attractive to employers. In fact even for the minority of students who may become future researchers, they will have a thesis to write and papers to give, so the issue of skills is not irrelevant to them!

As an example of balance, we may think writing skills are important, but we would probably not fail a student who struggles with writing but can "do the maths". Indeed students would feel hard done by if we did! On the other hand, are we not doing the majority of our students a disservice if we do not address their wish to get good jobs, and help them to understand what being employable means, by showing that we value generic as well as mathematical skills? And how are we to show we value something if not by giving credit for it?

We must of course be realistic about what we can achieve, where other parts of the educational system have not entirely succeeded, but a variety of practice is beginning to develop now, some of which begins to address the issue of making space in the curriculum. This is discussed below.

In what ways is skills development being addressed now?

In this section, we look not only at what is happening within our reviewed institutions, but also mention some developments in the wider world of UK Mathematical Sciences.

One useful wider initiative concerns the Skills Development working group convened by Stephen Hibberd on behalf of the HEA MSOR Subject Network. An example of activity linked to this group was a workshop on developing graduate and employability skills in mathematical sciences, reported in an MSOR Connections article [2]. The workshop contained not only contextual discussion, but also reports of skills development initiatives at a range of diverse institutions, giving a range of ideas for how skills can be developed in different contexts.

Two of these case studies concern concerted initiatives at two of the four institutions, both post-92, in our current study. We will not repeat the details, which are well described in the Connections article, but will comment that it is interesting that two institutions which may superficially appear similar have chosen different routes.

One approach, as reported by Sydney Tyrrell, involves skills modules in both first and second year which are compulsory for mathematical students, combined with a university-wide initiative labelled Add+vantage.

The other, Sheffield Hallam mathematics approach is reported in some of its aspects by Jeff Waldock. That report concentrates upon the online learning log which aims to encourage students continually to reflect upon their progress. The provision broadly aims to embed the development of skills throughout the curriculum at all levels, seeking opportunities to work on, develop and assess generic skills as part of mathematical modules, for instance in modelling or through a final year project. The general approach has been reported previously [5]. Here is one interview exchange about the IT skills aspect of this:

> *A: "... I know our students that go out on placement, what they're really appreciated ... for is their Excel skills ... something quite mundane really as far as the Maths goes but, you know we've had one or two that have sort of revolutionised offices they've gone into ... just with Excel"*
>
> *B: "Is it because you incorporate Excel in your modules that, that they get a large working knowledge.....?"*
>
> *A: "Yeah, that's it really, yeah."*
>
> *B: "Of Excel rather than having a course and this is how you do Excel?"*
>
> *A: "Yes."*

There are two points worth mentioning here. One is that in this case, curriculum time is not "lost" when skills development is integrated in mathematical modules, but it has been necessary to design and map the overall pattern of assessment to include a balanced programme of outputs such as posters, presentations and written reports as well as more traditional activities such as technical coursework and even examinations! Students develop their skills by exercising them and receiving feedback, and they receive some element of credit for this aspect of their work.

The other point concerns the mention of an industrial placement, which provides a major experience through which students inevitably develop their employability skills. This is discussed in [6].

Discussion

There is no consensus concerning the place of generic skills development in the HE mathematics curriculum for every course. In some courses it is a significant presence; in others it is conspicuous by its absence. Whose job is it to develop these skills? What if anything is to give way if skills development is to be included?

A glance at the widely accepted MSOR benchmark shows that the job should fall at least in part to the HE community - if we claim our students have these skills then should we at least show how we know, and what contribution we have made? Not all agree. Academics are chosen for their love of and enthusiasm for their subject and there is of course more to a university education than preparation for work, notwithstanding what we have written above. Is the secret then to find ways of and opportunities for incorporating skills development in our courses which work within our own contexts and allow us to stay true to our subject?

So, is current developing practice in any way transferable? Our gleanings suggest institutional approaches to skills vary: see for instance the contrast between Coventry and Sheffield Hallam.

However it may be that, if course designers are seeking to improve the generic skills development aspect of their mathematical courses, elements of experience and ideas can usefully be passed on and modified.

Ideas and questions

If readers are thinking about enhancing the generic or employability skills element in their courses, we suggest some questions they might like to consider.

- Is it desirable to have a separate skills module, or to integrate skills development into other activities in the course, or some combination of these?
- How can skills such as writing, presenting, and working with others be developed through mathematical activities, for example through modelling or project work, or indeed through mathematical modules?
- Could a learning log have a role to play in encouraging a reflective approach?
- If skills are to be assessed, what part should that assessment play in the overall pattern of assessment?

Whether you are doing something exciting with skills development, or you are looking to improve how you deal with your students' generic skills, or indeed want to take issue with what we have said, we invite you to contact us and join in the debate.

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7.3 *Does careers awareness have a place in the HE Mathematics curriculum?*

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Introduction

One of the questions we have been led to consider in our More Maths Grads musings on Mathematics in Higher Education is: “Is there a place for careers awareness in the HE Mathematics curriculum?”

Such a question might receive short shrift from some university mathematicians, concerned that our precious time with our students is already under pressure, and time spent on mathematics per se must take priority; universities have careers services, and it is their job to deal with careers awareness.

In contrast, we shall argue that to delegate this aspect of a student’s education and development completely to others who are not involved in the discipline is to miss a valuable opportunity to help our students to get the best from their time with us at university, and to send a positive message that we recognise and respect their aspirations. In this paper we report on various ways in which careers awareness is included in the curriculum already. This ranges from mathematical content and practice which implicitly provides contextual information about career possibilities, through the mechanism of industrial placement, to an example of innovative practice where careers awareness work has been explicitly included in the curriculum. Furthermore we shall speculate on the role of employers and alumni and whether there is any possible place for materials and practice developed through the MMG project outreach work with schools.

Before getting into details, there is one point that should be made at this stage. As students become more aware of the types of career that will be available to them as mathematics graduates, they will inevitably also become more aware of the types of skills and qualities which employers say they value. That is, the issue of careers awareness becomes inextricably linked to the issue of employability and skills development. We have written about employability in a related article [1], but if this current article also strays in that direction the reader should not be surprised.

The background and context

We take as given that the nature of higher education has changed in recent years. The overall participation rate has moved from low teens in the early 1970s to something around 40% in recent years, in spite of the fact that students now mostly take substantial loans to support themselves and pay their fees for their courses. More parochially, there was a 54% increase in the number of acceptances onto Mathematics courses between 2002 and 2007 [2], although it is necessary to realise that this period includes that in which numbers were recovering following the well-known difficulties caused by Curriculum 2000. A percentage increase in participation has happened to a greater or lesser extent across all entry routes, all ethnic groups, and all socio-economic classes, but we must keep this in perspective. The authors in [2] comment: “The growth from the low participation areas and the lower NS-SEC (National Statistics socio-economic classification) categories seems to suggest a positive trend in terms of Widening Participation to HE. However, it is worth noting that HE is still dominated by applicants from the highest participation areas.” Be that as it may, let us accept that we have a wide variety of people taking part, with a wide range of aspirations and backgrounds. It behoves us to try to understand this situation, and to make sure our practice is providing a positive and suitable experience for all of our students.

We have carried out our own investigations to try to understand the current situation. In induction week 2007 we surveyed 223 mathematical sciences first year undergraduates across diverse universities, both research-intensive and teaching-led. In answer to the question “Why did you choose to apply to university?” 93% of those students rated the statement: “I need a degree to get a good job” as ‘very important’ or ‘quite important’. The response was fairly uniform across the institutions. Evidently career development is a major motivator.

We then asked follow-up questions, both through the survey and through group and individual interviews in the next few weeks. We asked: “Why did you choose mathematics?” This is a question we also address in [3]. The most popular responses were enjoyment, being good at it, and wide job prospects. Also cited but much less frequently were challenge, earning potential, getting a respected degree, aiming for a specific career, and to learn more maths!

However when we asked what career plans they had, we found that fewer than half of those surveyed had any idea. For that minority that did, banking and finance featured prominently. We can only speculate on whether our pre-credit crunch results might have changed following recent events in the financial world. Accountancy, named separately from finance or banking, was also mentioned, and – a contrast at last – teaching. Others less mentioned included actuarial science, business and management, and earning a lot! Only a tiny minority mentioned careers - code-breaking, insurance, meteorology, statistics, research, "something with maths" – where specific high-level mathematical topics are a key requirement.

If we match our results against what actually happens to mathematics graduates, we find the stated ambitions of our sample of 223 students seem to be fairly typical. According to the Prospects website [4], which had data on 3455 mathematics graduates who graduated in 2007 (out of a possible 4250), the proportions in employment, further study or unemployed is given in Table 1.

	Mathematics	All disciplines
Entering employment in early 2008	47.4%	63.3%
Working and studying	15.4%	9.1%
Entering further study and training (including studying in the UK for a teaching qualification)	22.8% (7.2%)	13.9% (2.6%)
Believed to be unemployed	5.9%	5.5%
Other	8.5%	8.3%

Table 1
Summary of what 2007 Mathematics graduates were doing in early 2008, compared to all disciplines (source [4])

Resisting the urge to speculate about what may lie behind these figures, we shall merely draw attention to some interesting features. Mathematics has an employment rate considerably lower than that for all disciplines, with a correspondingly higher proportion continuing to study, either combining that with employment or not. The proportion studying for a teaching qualification is well above that for all disciplines, a figure to be welcomed as helping to address previously identified shortages of mathematically qualified teachers in the UK [5].

The figures for those in UK employment, or combining UK employment with further study, (2105 mathematics graduates) are further broken down by Prospects as in Table 2. It is obvious that the finance industry is far and away the largest absorber of Mathematics graduates from the UK, and the early aspirations of our sample reflect that.

Having explored what our new students said they aspire to, and what graduates actually do, we might next look at whether there is a difference of perspective between what students' overall aspirations are, and the preoccupations of the academics teaching them. There is a stereotypical view that mathematics academics are entirely focussed on the development of their subject, rather more so than their students. As we interviewed academic staff at the same four institutions, we found a complex range of responses to this issue, and this first interview comment reflects that complexity.

> *"Q: What are their aspirations in terms of, ... why do you perceive they're doing a degree, ... why have they chosen maths and what do they intend to do long term? I mean does that affect the way that you approach things or the way you try and persuade them into working?*

> *"A: I've never thought that deeply about that level in terms of how that feeds through into my teaching, if I'm honest. I teach a course because I enjoy it, ... that's my main way of motivating people is ... the love of the subject, certainly for a first year course, where you're just saying "right, we're going to learn calculus because it's an important thing", I think that's the right approach, not because you know in so many years time you're gonna be glad you learned this. I'm not sure if even that's true. Now, oh no, students come to do maths for a wide variety of reasons as far as I can tell. Some just liked the subject when they were doing 'A' Level, they come to university because it's the next thing to do and maths seemed to be the thing to do. Some people perceive maths as being a good degree cos it's numerate and has a potential to lead onto good jobs at the end of it, some come thinking I'm gonna be an accountant and maths is something I can do for three years and that looks like a good route into it to be an accountant, though I doubt how much of their maths degree they'll use to learn accountancy. Some really, I think, come thinking you know if they might want to be an academic, but I think that's a very small handful of students, but they are there and you can identify them. So yeah, all kinds of, some end up on the maths degree because they couldn't get into another degree."*

Some responses are gloomily pragmatic.

> *"The job market for maths grads is excellent at the moment, most of them earn more than I do even, you know, a few years after university even if they don't have a very good degree classification. So I suppose those are the overwhelming reasons why students choose maths, nothing very positive, I do try to inspire them and some of them are inspired but realistically the ones who sort of have a genuine vocation and are going to go on and do research in maths are always going to be a small number."*

In some cases, though, a cheerful awareness of student aspirations becomes evident.

Business and Financial			39.9%
breaking down in detail as	Chartered and certified accountants	9.7%	
	Finance and investment analysts/advisers	8.8%	
	Actuaries	6.7%	
	Other business and finance jobs	4.3%	
	Management consultants and business analysts	2.6%	
	Organisation, methods and business systems analysts	1.7%	
	Examiners/auditors	1.6%	
	Taxation experts, tax inspectors, consultants, advisers	1.6%	
	Statisticians	1.5%	
	Brokers	1.3%	
Education			8.5%
Commercial, industrial and public sector managers			8.4%
Retail, catering, waiting and bar staff			6.5%
Other jobs			6.5%
Numerical clerks and cashiers			6.0%
Information Technology			5.0%
Other professional and technical jobs			3.6%
Marketing, sales and advertising			3.1%
Engineering			1.4%
Arts, Design, Culture, Media and Sports			1.1%
Scientific research, analysis and development			0.7%
Social and welfare			0.7%

Table 2
Breakdown of types of work for 2105 Mathematics (2007) graduates in work or combining work and further study in early 2008 (source: [4]) Disciplines included in Mathematics are Applied Mathematics, Computational Mathematics, Engineering Mathematics, Industrial Mathematics, Mathematical Methods, Mathematics Modelling, Mathematics not elsewhere classified, Mathematical Mechanics, Numerical Analysis, Numerical Methods, Pure Mathematics.

> *"You know, we get all wrapped up in the syllabus and maths, definitions and proofs but, but our typical student ... wants a good 2(i) and a good job."*

Having explored the context and set the scene, we now go on to specifics. Should there be a place for developing careers awareness on our mathematical courses? If so, how can this be done in such a way that student aspirations are respected and acknowledged, while the strengths and enthusiasms of mathematical academics are positively exploited?

Can we enhance careers awareness?

How do we, as a community of university mathematicians and educators, maintain good focus on our discipline, encourage and stretch the born mathematicians, exploit the enjoyment that many students get from mathematics, but at the same time acknowledge and support the life aspirations of the whole range of our students? We shall discuss a variety of ways in which student aspirations as regards career development can be, and indeed are being acknowledged. These will include use of realistic problems and examples in the curriculum; direct contact with employers, whether through industrial placement or otherwise; extra-curricular activity such as talks by alumni; and finally one example of innovative practice where professional development is being directly addressed in the curriculum.

"Real" or at least realistic problems

Students will often work upon mathematical or statistical modelling problems, in taught modelling modules or individual projects, which started life as a real industrial or similar problem which required the input of mathematicians amongst others for a solution. They may also take particular applied modules, for instance in areas such as financial mathematics. Whether these activities involve exploiting real, large data sets in a statistics module, or understanding the mathematics behind the madness of the financial derivatives market, or having students tackle a problem on choosing the site of an oil well, modelling pollution in the Great Lakes, or modelling the progress of an epidemic, they inevitably contain an implicit message, which can and perhaps should be made explicit, of where mathematics and mathematical graduates can fit into the scheme of things.

There are decisions to be made here about how messily realistic the problems should be, or to what extent any problem needs to be pre-digested before an undergraduate can deal with it, and of course in that process we can end up making the problem less real. This deserves careful thought, given students will have had plenty of experience at school with idealised problems. Whatever decision we might make there though, we can bear in mind when setting up modelling case studies that we can retain and make explicit the original context, drawing out careers lessons, even if the problem eventually tackled has been scaled down.

It is true of course that opportunities such as those described to exploit multiple applications of mathematics do not exist in every mathematics degree. Mathematics degrees are diverse, as are the things which motivate students of mathematics, and long may it remain so. For instance, some students may not be strongly motivated by employment destinations, but by the sheer beauty of abstract mathematics. We believe that it is as important that potential students understand that not all mathematics degrees are the same, as it is that they understand possible career destinations, and we have been working with others on a Maths at University booklet to help students choose the courses which suit them, and match their aspirations best [6]. This booklet is being made widely available. An important part of enhancing careers awareness is to enhance the awareness of the widely varying nature of mathematics degrees.

Industrial placements

Two of the four universities in our sample place substantial emphasis upon the benefits of doing a one year industrial placement and achieving a sandwich degree, and there are other instances of this around the country. Whilst this opportunity is not taken up by all students, those students who do participate bring back in their final year substantial experience of employment, as well as a greater maturity. At one institution, returning students report on their experience through a major poster presentation fair. This may be attended by representatives of the placement employers, as well as other students. In fact second year students must attend this session as part of their own consideration of and perhaps preparation for placement; other final year students must also attend as part of one of their final year modules.

Extra-curricular vehicles for developing careers awareness

Of course whether one chooses to devote curriculum time to the kind of activities which enhance careers awareness or not, one should also be aware of the range of extra-curricular activities which can help, apart from pointing students towards the university careers advice service.

A range of activities involving interaction of employers with school students has been evolved and piloted through the outreach teams of the More Maths Grads project. One must be aware that these activities were designed with a particular purpose in mind which does not translate immediately to universities. In schools we aim to persuade younger people of the benefits of studying mathematics at university by exposing them to some of the range of exciting futures to which such study can lead. At university, from the point of view of keeping the mathematics ecosystem healthy, we may aim to have students graduate with their enthusiasm for mathematics at least intact, and preferably enhanced, so that they will take with them a positive message about studying mathematics and where it can lead.

As the MMG project reaches its end, all university mathematics departments will receive "More Maths Grads in a box", which will contain details of the range of successful school outreach activities developed and trialled, including those which involve employers, and this would bear some scrutiny. Perhaps undergraduates may be encouraged, or even paid, to be involved in running outreach events on lines which have been tried and tested, and will implicitly enhance their careers awareness through this. It is however difficult to see how a curricular contribution can be made directly, although enhanced contact between departments and employers may lead to development for instance of projects and modelling case studies, and more general awareness could inform a module such as Professional Development as described later in this article, although perhaps the student-driven research approach is more appropriate in a higher education context.

Departments can also exploit their own natural resources to help current students to understand their possible futures in employment. Alumni can be keen to come back and talk about what they have achieved after graduation, and occasional talks involving them can be organised through the department or via a student Mathematics Society if such a thing exists.

Curriculum innovation to enhance careers awareness

In some cases, modules or part-modules can be designed specifically to enhance careers development. Such modules can appear in any year of a course, and they may be designed as much as a focus for generic skills development as specifically for careers awareness, although an awareness of the value of one's generic skills is part of an awareness of careers development. Even if they are only about generic skills, though, we have argued in related articles that these skills coupled with certain generic mathematical skills, attitudes, abilities and behaviours carry great value, and even if some specific mathematical topics are displaced, that is a consequence that is worth bearing, and one which will not damage the quality of our mathematical graduates [1].

We will mention now, though, one particular initiative which explicitly addresses careers awareness – Professional Development at Sheffield Hallam – which is described in some detail in an accompanying case study [7]. In this final year, 10 credit module, students carry out a group research activity in which they investigate various aspects of the place of mathematical sciences and mathematical graduates in particular industries. Returning sandwich students work alongside full time students and experience is shared through presentations and reports. We might ask what students gain from an activity such as this – with a broad brush look at mathematical sciences in the world of employment, rather than doing concrete mathematics on real problems. One benefit comes from the fact that everyone sees everyone else's presentation, so there is a sharing of experience and all get a breadth of view of the applicability of their discipline,

Conclusion

The question raised in the title of this article goes right to the heart of what a degree is. There is a caricature of maths academics, that they are mainly or only interested in their research, and that they regard the undergraduates as an annoying distraction, at best only there to be harvested for the next generation of research students. Our experiences over many years, and most recently our investigations through the More Maths Grads project, have reassured us that the situation is more complex than any caricature. One aspect of that complexity is that many academics may have a positive view of the intrinsic value of education, and a desire to pass on a love of their discipline rather than seeing themselves as career developers.

There is nevertheless a duty incumbent upon maths academics, many of whom have a career trajectory whereby school is followed by university and then by a research career, to be aware themselves of the kinds of careers into which their graduates go, to consider what their graduates aspire to, and to review how their practice can take this into account.

There is gradually growing awareness of our students' wide ranging needs and aspirations in a changing world, and growing discussion of what should be our role in helping students to achieve what they wish from their degree. This article aims to provoke further growth of that discussion, so that our mathematical courses leave our students broadly satisfied that their wide range of aspirations have been acknowledged, respected and taken into consideration. We hope that this in turn will lead to a healthier mathematical ecosystem, where students grow into doing mathematics, they choose to do a degree in a mathematical subject, they find the degree helps them to achieve their aims, whether these concern employment, further study, or enjoyment, and they then take a positive message back to the next generation.

What then of the view that mathematics degrees should only be about mathematics and that the proper place for careers awareness is extra-curricular? While it is true that a major reason students give for choosing mathematics is that they enjoy it for what it is, they are also keenly interested in the employment possibilities it raises. Students feel well supported when they feel that they form part of a mathematical community, with a full and healthy educational relationship with tutors, and part of such a relationship is that tutors show an interest in where students are going next. Of course such development work can be extra-curricular as well, but if we as senior members of our mathematical communities want to show we value such activity, we must be prepared to acknowledge and perhaps to credit it. We could just leave all this to, and encourage the use of the careers service, but we perceive that such encouragement achieves more credibility when seen as part of what the mathematicians in your own community say they value.

We propose that a wider awareness, of the applicability of mathematics and of the stories of mathematics graduates, not only improves employment prospects but does so because graduates become more employable when they can articulate the benefits of a mathematical way of thinking in many different employment situations. It can also inspire students when they have a clearer idea of where they are going, or what they need to do to get there. We hope to challenge and provoke the mathematics community to join in and debate these issues.

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7.4 *Foundation degrees and the mathematical sciences - a discussion*

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Introduction

What is the place of Foundation degrees involving a significant component of the mathematical sciences, within the spectrum of courses provided by the Higher Education (HE) mathematical sciences community in the UK? What are the rationale and scope for developing such provision, and how does that fit with the "employer engagement" agenda?

The Higher Education Funding Council for England (HEFCE) has identified that the primary aim of its developing strategy for employer engagement is "to support the HE sector to meet the higher level skills needs of employers, employees, economy and society" [1]. One of HEFCE's major initiatives, already contributing strongly to the strategy for employer engagement with HE, is support for the expansion of Foundation degrees. Our opening questions are motivated by this initiative. As part of our work for the Higher Education curriculum theme of the More Maths Grads project, we wish to improve our understanding of how the HE mathematical sciences community may be able to contribute to this agenda.

The issue of enhancing the level of workforce skills in the UK is the subject of considerable attention, perhaps most notably through the Leitch Review of Skills [2]. Leitch concludes that if the UK is to achieve world class skills, it will be required "to commit to achieving by 2020, world class high skills, exceeding 40 per cent of the adult population qualified to Level 4 and above." Leitch discusses how such percentages are to be attained, but he says vis-à-vis the 2006 government target that 50 per cent of the population aged18-30 should participate in HE by 2010:

> *"Concentrating too much on younger age groups could create further longer term problems for the amount and the use of high level skills in our workforce. With more young people qualified to this level and fewer older people, it increases the likelihood of poor deployment of higher-level skills with relatively under-skilled owners, managers and leaders unable to find the best uses for new graduate recruits. As the Higher Education White Paper stated, new higher education growth should not be 'more of the same', based on traditional three year honours degrees. Rather provision should be based on new types of programme offering specific, job-related skills such as Foundation Degrees."* [2]

These Foundation (FdSc or FdEng) degrees are seen as generally more demand-led and employer-focussed than traditional three (or four) year honours degrees, and more about their nature and current state is presented below.

How do things currently stand in the mathematical sciences with respect to the Foundation degree agenda? Foundation degrees involving mathematics or indeed any of the mathematical sciences as a named component in the title are an extreme rarity. In fact at the time of writing (late 2009) there is only one such course offered in the UK, the FdSc in Computing and Mathematics at London Metropolitan University. A few details of this course are described later, but it seems that so far, where the UK HE mathematical sciences community is involved in Foundation degrees, it is mainly through providing general mathematical support, "service" mathematics, on more obviously vocational courses, often aimed at particular industries and designed in collaboration with particular companies or groups of companies. An example from the authors' own institution is FdEng Railway Engineering, designed to contribute towards satisfying the upskilling needs of companies involved in the railways including Network Rail, Jarvis and Balfour Beatty.

In this case it would seem to be useful to assume that many readers of this article, most of whom we anticipate will be from the mathematical sciences community, will not be over-familiar with the detailed aims and nature of Foundation degrees. We shall therefore describe some of the features of these courses before going on to any further discussion.

What is a Foundation degree?

Foundation degrees were introduced by the Labour government in 2000, and according to the QAA Foundation degree qualification benchmark they should aim "to provide graduates who are needed within the labour market to address shortages in particular skills". [3]

The courses are *"aimed:*

- *to meet the needs of the economy to have people qualified with intermediate higher technical and professional skills*
- *to increase and widen participation in HE by providing a new and accessible route into higher education."* [4]

They are recognised as an award that would be generally equivalent to level 5 within the national qualification framework (NQF); that is, students would generally study at levels equivalent to the first two years of an English Honours degree (NQF levels 4 and 5). In this respect Foundation degrees resemble the old BTEC Higher National Diplomas, although we shall see that in an ideal world, they would be designed to be much more focussed on, and emerging from the needs of industries and companies. Each Foundation degree must have associated with it the opportunity of a "top-up year"; that is, the opportunity to progress to further, honours level study for those able to benefit from it.

Foundation degrees are not to be confused with courses which are often known as foundation years, otherwise known as preparatory years, year 0s, or extended degrees. These latter form another route into higher education whereby students study at university or college for a pre-degree year at NQF level 3 before proceeding onto the first year of a degree programme. It is unfortunate and a little confusing that the word "foundation" has become associated with two distinct but not particularly distant aspects of provision.

Much more useful information about foundation degrees can be gathered from the QAA website [3], and from the Foundation Degree Forward (*fdf*) website [5]. We shall not repeat every single detail of what is on those sites, and others to which they refer, but we shall pick out a few key facts which may inform and enrich our discussion.

Foundation degrees are intended to be employer facing and demand led. Courses can be either full time or part time; thus students may be either full time students with or without prior work experience, or part-time students who may be in work and perhaps in some cases sponsored to attend or study.

Sector skills councils (SSC) [6] have a key role in facilitating collaboration between employers and providers of foundation degrees, particularly at the instigation and design stages, and Foundation Degree Forward provides support, not least through a range of useful publications, for example [7]. The SSC with nominal brief for the mathematical sciences is SEMTA (Science, Engineering and Manufacturing Technologies) [8], but given the widespread applicability of mathematical sciences, other SSCs may be as likely to have an interest in numerate developments, e.g. COGENT (Chemical and Pharmaceutical, Oil, Gas, Nuclear, Petroleum and Polymers) [9] or FSSC (Financial Services, Accountancy and Finance) [10].

Work based learning must be a significant component of foundation degrees. This may be addressed by work-based tasks if the student is in work and studying part-time or perhaps through a work placement and/or integrated and pervasive work-related tasks in modules if the student is studying full time. The QAA benchmark statement for Foundation degrees says:

> *"Foundation Degrees integrate academic and work-based learning through close collaboration between employers and programme providers. They build upon a long history of design and delivery of vocational qualifications in higher education, and are intended to equip learners with the skills and knowledge relevant to their employment, so satisfying the needs of employees and employers."* [3]

In a statement which may be particularly relevant in considering what offering may be made from mathematical sciences, the benchmark says:

> *"Although many Foundation Degree programmes are designed to meet the needs of the local employment market, some Foundation Degree programmes are targeted at national and international employment needs."* [3]

Much play is made of the distinctive offering of these degrees:

> *"The distinctiveness of Foundation Degrees depends upon the integration of the following characteristics: employer involvement; accessibility; articulation and progression; flexibility; and partnership. While none of these attributes is unique to Foundation Degrees, their clear and planned integration within a single award, underpinned by work-based learning, makes the award very distinctive."* [3]

This has been partly described here, but interested parties are firmly recommended to visit the websites to which we have referred to gain a fuller picture.

Finally, the Foundation Degree Forward publication "Developing higher skills in the UK workforce: a guide to collaboration between higher education and employers" [7] offers interesting advice on ways of identifying skills needs, and on experiences of and strategies for stimulating demand. This may be useful in addressing any possible significant role for the mathematical sciences.

Having looked at some aspects of the specification for Foundation degrees, it is interesting to look at how things are actually working out in practice. Some statistics can be found on the HEFCE website [11] under the heading "Foundation degrees: Key statistics 2001-02 to 2007-08". These are the latest figures to have been published by HEFCE at time of writing.

We shall quote a few choice figures from this HEFCE document. They say "*...nearly 72000 students were registered, or were expected to register, on Foundation degree programmes in 2007/8*". The number of new entrants rose from about 34000 in 2006/7 to over 40000 in 2007/8. Almost half of all students were studying the three most common subjects: education, business and art and design. 56 per cent of courses in 2005/6 were wholly taught in FE colleges.

In 2005/6 62% of Foundation degree students studied full time and so 38 per cent were part time. The document says, "*Distance learning was the main means of study for 16 per cent of part time students*." An estimated 80 per cent of part time students at higher education institutions had some employer support such as study leave, but only 36% received any financial support.

In a figure which may have a bearing upon our thinking in mathematics, HEFCE estimates the proportion of foundation degree students with A Levels at between 11 and 33 per cent, with the upper end of the range being the more likely. Breakdown into A Level subjects is not presented.

The HEFCE document rather interestingly comments that:

> *"Foundation degrees are not 'flexible' in the ways often envisaged. More than half of students entered full-time programmes, there is little movement between full and part-time programmes or between institutions and most programmes have a definite course length."* [11]

Having seen some of the rhetoric and a little of the reality, we are ready now to progress to a look at this type of development from the perspective of the mathematical sciences.

Some preliminary issues for mathematical sciences

Let us begin by stating the obvious. There is no mathematics industry. Mathematical sciences must be many things to many people, and employer needs in this respect range from a stated wish for a more numerate workforce [2], through to highly qualified scientists with particular specialist knowledge.

A wealth of information on needs and demand is gathered by SSCs. For instance SEMTA publishes *Skills Action Plans* by sector [12], and skills needs are analysed in some depth. While industrial sectors, e.g. bioscience, are identified, mathematics or statistics generally only appear as a subcategory. For example, in the Bioscience Sector Skills Agreement Stage 1: Skills Needs Assessment [13], one indicator is HtFVs (Hard to Fill Vacancies), and it is identified that 8 out of 70 Bioscience industrial sites surveyed reported HtFVs in mathematics/statistics, but this is to be compared with 19 sites in biological and medical sciences, and 22 sites with HtFVs in generic disciplines (e.g. regulation, project management, QA/control, sales and marketing). There are two points to note here. One is that information on demand for mathematical scientists does not come pre-digested from sources such as this. The other is that shortages of high level skills are not restricted to mathematical sciences.

How else can we assess potential demand? There is a dearth of Foundation degree courses with Mathematics in the title, but we cannot necessarily infer from this that there is no industry out there currently seeking, and failing to find a specifically mathematical partner, at least not to develop a Foundation degree. It does, though, suggest that we need more work to identify the form of any potential demand. We are looking at what the mathematical sciences have to contribute, but in these relatively early days of Foundation degree development, it is not yet clear what part a mathematical FdSc could actually play, or what demand there could potentially be, either for upskilling existing workforce or for providing alternative routes for full time students. The Foundation Degree Forward publication "Developing higher skills in the UK workforce: a guide to collaboration between higher education and employers" has some interesting points to make about identifying needs, and the requirement sometimes to stimulate demand:

> *"HE providers need to be proactive in promoting what they can deliver to meet employer and employee needs. This is particularly the case with Foundation degrees which, despite their growth and focus on meeting employer skills needs, are still relatively new and unfamiliar to many employers."* [7]

It proceeds to give examples of how this has happened in some cases, and reading these examples stimulates some questions which we in the mathematical sciences community must address if we are to engage with the Foundation degree agenda. What is the demand, latent or otherwise, for significantly mathematical FdSc courses, and how do we identify it? Once identified, how would we propose to interact with whatever is the appropriate range of employers to engage them in designing a course to satisfy the demand we have identified (or created?), and what is the most appropriate offering? Would targeted, highly focussed short courses around particular technical topics for particular industries be more appropriate? What would be the difference between such a Foundation degree course and a BSc involving mathematical sciences which lies at the extreme practical end of the QAA Mathematics, Statistics and Operational Research (MSOR) benchmark [14], with compulsory industrial placement for full time students? What would be the key design issues?

We shall begin to address these questions by first describing current Foundation degree provision in mathematical sciences; then we shall speculate about one or two other possible models with the aim of understanding the issues more clearly.

Current Foundation degree provision in mathematical sciences

The only current Foundation degree course with mathematics in the title is FdSc Computing and Mathematics, run by London Metropolitan University. Brief outline details of the structure of this course are given in Appendix 1.

It is interesting to see how the course designers have dealt with the structural and other constraints, and how things have worked out in practice. The course is offered in both full and part time mode, but so far all students have been full time. Recruitment tends to be heavily influenced by communication links such as tube lines. Numbers on the FdSc are small, and have never been more than 12 in any given year, making the provision vulnerable. A Level Mathematics is not necessary for entry, and recruitment is mainly through clearing. The "top-up" offering is a BSc in Mathematical Sciences, and some bridging study may be necessary. In the interests of viability, mainstream teaching and modules are common with BSc classes, although FdSc students are given extra support. Transfer to the BSc without loss of time is possible at various stages with the first opportunity being at the end of semester 1. The possibility of conditional transfer is a strong incentive to work hard from the start for those on the FdSc, many of whom would be striving to recover from poor A Level results. Indeed this is identified as a key selling point.

The work-based learning issue is dealt with structurally by making the whole of Semester 4 an academically credited Professional Industrial Placement, a 60 credit module with work-related objectives agreed between employer and academic supervisor. Placements are available in a range of local businesses, with nature of work using a combination of computing and mathematical skills. However, experience of this cannot be reported as all students capable of progressing on the course so far have transferred to the BSc course before reaching Semester 4.

Some possible models

We now turn to a speculative consideration of possible models through which Mathematical Sciences could contribute to the agenda for employer engagement by operating Foundation degrees. We follow this approach because at the moment there is no clearly identified demand and therefore no clear path to satisfying that demand. What we discuss obviously does not comprise an exhaustive list of possibilities. First we present these models, in some cases as stories from which we may learn, and then proceed to suggest a possible way forward.

Model 1: FdSc Mathematics with X

In Model 1 we have taken the obvious step of assuming that any FdSc course would reside at the "practical" end of the MSOR benchmark [14]. Taking this thinking a little further, we have assumed that a title such as FdSc Mathematics would not be suitable, as the word "mathematics" by itself carries too many theoretical connotations for those outside the discipline, especially if they are running a business with particular needs. Instead it would seem appropriate to have a title "FdSc Mathematics with X". The mathematics could then be seen to address a generic need for upskilling in practical mathematical and statistical approaches while the X would be designed to satisfy the requirements of a particular employer or group of employers. This would allow the flexibility to have a wide range of possible Xs reflecting the spectrum of employers using mathematics. Mathematical sciences would be the major discipline, providing 160 credits, and X would provide the remaining 80 credits. Indeed Mathematics with … is not an uncommon course structure for BSc degrees in HE.

To illustrate this, we shall discuss a particular structure which is given in outline in Appendix 2. It takes the form of FdSc Mathematics with Business, which we felt was generic and illustrative enough to consult upon with employers. We proposed the course should aim to make its students highly numerate; skilled in the use of commonly applicable mathematical and statistical approaches to solving practical problems in business and industry; skilled in the use of technology, both for everyday purposes and to implement mathematical and statistical approaches; enterprising, business aware and with well developed key skills such as communication, team-working, self-management, etc.

We perceived that the situation regarding full time and part time courses would be different, and decided to concentrate on part-time provision. The reasoning behind this was as follows. A full time course may indeed, as in the case of London Metropolitan, provide an alternative route into degree level mathematical study for those who are not qualified to enter a BSc course directly. Indeed it may be designed, and ideally suited, to sit alongside a practically orientated BSc course. While there are other valuable routes in for such people, such as Year 0s, an FdSc route would allow the possibility of progress without loss of time, as well as offering a vocational route which may be more appropriate. However, the viability and sustainability of a full-time course would depend upon the demand. In the case of London Metropolitan demand is fragile, and tied to a particular geographical catchment area. In each region, institutions will make their own decisions about whether to enter such a market, and what part that could play in addressing the employer engagement and workforce upskilling agenda from a mathematical perspective, but a general approach on the part of the community does not seem appropriate.

We designed our consultation, then, to address a course aimed at people who are currently in employment but looking to study part-time in order to progress. Such a course would address the employer engagement agenda directly, affording natural opportunities for work-based learning by linking mathematical developments to workplace needs. In an attempt to pre-empt the viability issue, we considered distance learning as being the desirable mode of study, with students supported by notes and worksheets, by a highly interactive virtual learning environment such as Elluminate [15], and perhaps by occasional block release and study schools. In this kind of mode the course could be offered nationwide, and therefore draw its students from the widest catchment area. Care would be needed with design of any residential components, as employers would want to minimise costs of releasing students for blocks, and of paying for their accommodation and travel.

This brings us to the issue of entry requirements. In spite of up to 33% of current FdSc entrants having A levels, we have no information about how many of these would possess A level Mathematics, but anyway in a spirit of accessibility, we would want to make the course as open as possible to people in work. We thus tentatively proposed entry requirements either of AS Level Mathematics, or equivalent numerate vocational qualification, or GCSE Mathematics plus a bridging course.

In retrospect we should not have been so prescriptive. Briefly considering again a *full time* mode for a course such as this, we would have to allow for the likelihood, illustrated by London Metropolitan's experience, that numbers from any given catchment would be small. To maintain viability in that case, common teaching with other programmes would be necessary, and that could cause problems if those programmes have widely different entry requirements. However if we are designing a national part time distance learning programme, viability considerations would be different, and entry qualifications could perhaps be set, within the overall constraint of maintaining educational standards, to optimise participation rates from the national workforce.

From these design musings we were ready to find out about some employer views of our proposal. We took the model proposed in Appendix 2 to SEMTA, as the SSC with primary responsibility for mathematical sciences, surrounding it by a short consultation questionnaire, the questions from which are presented in Appendix 3. The proposal was to seek feedback from employers in the areas covered by SEMTA as to the usefulness of such a course. Biosciences employers were the only grouping which was judged by SEMTA to show an interest. No consultation forms were filled in, but there was a verbal report from a meeting of a forum of senior people from this group of employers. The employers were interested in the proposal, but suggested that while the industry did perceive a need for a more numerate workforce, this need falls into two categories: on the one hand there is a need for the general workforce to have a higher level of numerate awareness and confidence, and on the other, there is a need for specialised and highly qualified statisticians. This Foundation degree proposal was perceived as falling between these two needs.

Model 2 Contributing to employer focussed, demand led Foundation degree courses in other subjects

Mathematics is not only "queen of the sciences", but also has a major role to play in disciplines which do not think of themselves as sciences. As a community we already contribute support in mathematics and statistics - servicing - to a range of Foundation degree courses. Mode of study is a prime concern for employers supporting employees to study part-time on Foundation degrees. Travel and attendance costs for students attending block release weeks away from home can be a critical factor in what employers will support. A move to more blended learning, mixing distance learning, online support, and perhaps occasionally face-to-face contact, can render a course more accessible and therefore more viable. A negative factor here is the upfront investment required to develop good quality blended learning approaches and materials, in such a way that they are made relevant to the work context from which the students come.

Model 3: FdSc X with Mathematics

Models 1 and 2 are of course not the only way forward. We have not so far considered for instance the possibilities of FdSc X with Mathematics. As one example we could mention our own institution's recent launch of FdSc Integrated Engineering, where a common first year leads to outcomes in Mechanical, Manufacturing, Operations or Electrical Engineering. We are currently investigating whether the identified demand for those four routes would extend to a fifth route with a more mathematical outcome, with specialised modules in modelling, numerical methods and techniques as well as a more mathematical work-based project. We ask, could we as a community be more proactive in contributing innovative material and minor strands to courses addressing demand identified by others who do have an identifiable industry base? An interesting aside here, is to note that this FdSc Integrated Engineering is to be entirely delivered by partners in Further Education, as was 56% of FdSc provision nationally in 2005/6, and the question will arise as to whether FE colleges will normally have the skills base to deliver a range of higher level mathematics modules.

A possible way forward

From these musings on possible models springs an idea for an initiative which could be proposed as a programme of work under the national STEM project following on from More Maths Grads. A consortium of universities would be formed. One might wish that this would include the Open University, as they have by far the most experience and expertise in producing distance and blended learning materials, and in operating courses in that mode, but it would be helpful if they were joined by other partners who would bring complementary experience of running a broad range of Foundation degrees with a range of industries.

The partners in this consortium would perform three tasks.

- They would carry out demand identification and stimulation work focussed through an event or events involving not only SEMTA, but also COGENT and FSSC, together with Foundation Degree Forward and representatives of employers. Discussions would involve possible offerings of FdSc Mathematics with X, as a single national programme supported across the country at least in part time distance learning mode as in Model 1. They would also discuss possibilities of FdSc X with Mathematics as in Model 3. Depending upon the results of this, the consortium would then make progress in constructing an appropriate offering or offerings to match demand.
- The consortium would co-ordinate the creation, gathering and/or collation in a central repository of a range of basic modular materials, some on techniques, but most importantly examples, case studies and scenarios gathered from many industrial, commercial and work-related contexts, in a way suitable for use in blended learning in service teaching on Foundation degrees. In this way, upfront costs of material development in a move to blended learning could be shared, as could the hard-earned experience of providing work-related examples.
- The consortium would act as brokers and developers amongst providers of blended learning modules on Foundation degrees to share successful ways of working with blended learning approaches to mathematical sciences, particularly where the learners are situated in their workplace.

This initiative would of course have to face the issues faced by all such centralised projects, such as obsolescence (as has happened for example with Mathwise), difficulties with transfer (as with for example computer-aided assessment), and specialised needs (for particular industries, or particular technologies). Such issues are surmountable, perhaps by keeping the approach simple, with an excellent example of a successful simple approach being provided by the mathcentre initiative.

Discussion and summing up

If we allowed our deliberate optimism and naïveté to prevail we might have hoped that, given the widespread assumption that a more numerate workforce is a good thing, we could identify some demand for a highly numerate FdSc, match our design to that demand, and pilot a course. In the event, we could not muster enough evidence of direct demand for such a course even to convince our own institution to run one, in spite of that institution's fundamentally positive attitude towards Foundation degrees. However it is apparent as we have looked at possible ways forward above that potentially viable avenues remain open.

We have already been through much discussion in the earlier stages of this paper, and we provide structure for our remaining discussion through a short list of key questions, with the aim of providing some focus for whoever may take this work further. We provide our own discussion points under these headings, but repeat that we believe the logical way in which this work should be pursued is through the national STEM project.

1. Where would demand for a Foundation degree with significant mathematical content come from, and what could we do to stimulate it?

   This is a key question. We argued earlier that designing a full time course would be likely to provide an alternative small minority route into HE, but source of demand is not clear, it would not directly address the workforce upskilling agenda, and it would bring design/viability problems of its own. We have speculated about a national part-time programme offered through blended learning. While no single employer is likely to commission such a programme, a co-ordinated national programme serving many employers may achieve sustainability and viability. A wider co-ordinated look at needs analysis is required, and we have proposed this be taken forward under the STEM project.

   As for the stimulation of demand, reference [7] reports upon ways in which demand and awareness have been raised in other areas, and also provides useful practical advice on how to manage such events. We have proposed that an event or events would be useful which bring together potential providers from HE, all relevant Sector Skills Councils (not only SEMTA but COGENT, FSSC, etc), and Foundation Degree Forward. One would ideally also want direct employer representation, but given the observation made earlier that there is no mathematics industry, and that we propose seeking viability through a national programme, care would have to be taken to ensure that employer views reflect the full spectrum of mathematical needs of different industries. Indeed it may be that with a generic subject such as mathematics there is no single representative view!

   There is parallel work on the More Maths Grads project taking place between a team at the University of the West of England and certain employers in the South-West of England. This suggests that their upskilling needs would be best satisfied by highly focussed and customised short courses rather than a longer term commitment to courses such as FdSc. There must be a clear committed view of what FdSc courses offer, and [7] (p.16) provides a researched list of key promotional messages.

2. How could the design and execution of the programme be managed to maintain viability of the provision?

   We have proposed that a consortium be formed to analyse and perhaps create demand, and would add that that consortium would be the logical forum to continue to the design stage. It would be premature here to suggest how a single national programme may be run, and that should be an issue to be faced by the consortium.

3. What is the best way to deal with entry qualifications to an FdSc Maths with X?

   There will obviously be a close relationship between entry qualifications and demand. We would propose aiming to be as inclusive as possible, but are also aware of the need to be mindful of standards, not only of the Foundation degree where constraints may be more general, but also in any Honours top-up year. Might we suggest that for the FdSc to be worth running it will have lower entry requirements than any parallel BSc provision in Mathematics, and that the top-up could not reasonably be single honours BSc Mathematics?

4. Does the mathematical sciences community have the will, through the medium of the STEM project, to pursue a co-ordinated approach to "service" mathematics in a work-based learning environment, such as that described in Model 2 above?

   This question refers to a further way in which mathematical sciences can continue to make a contribution to workforce upskilling. We might supplement it by asking whether the modus operandi proposed in Model 2 and subsequently, designed and run co-operatively, could work.

We close this discussion article by noting that there is a contradiction here. Foundation degrees are supposed to be employer-focussed and demand led, but much of our discussion has concerned demand identification and stimulation. We encounter statements that a more numerate workforce is desirable, but clearly need to understand better exactly what mathematics is involved. Of course, this does not mean the HE mathematical sciences have nothing to offer to the employer engagement agenda, but it does mean we have to be imaginative in the ways we might contribute to that agenda as far as it concerns Foundation degrees. We have proposed that there are avenues to be followed through the national STEM project, and we believe our proposal for a national approach to demand stimulation and course and material creation presents a viable way forward.

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Appendix 1 Outline of FdSc Computing and Mathematics course at London Metropolitan University

Total credit 240 points Mode Full Time (2 years) Part Time Day (3-5 years)

Four modules per semester over four semesters

Semester 1	Logic, Mathematical Techniques 1, Introduction to Programming, Personal Study Skills
Semester 2	Introduction to Data Analysis, Mathematical Techniques 2, Personal Development, Introduction to the Internet
Semester 3	Foundations of Statistics, Further Mathematical Techniques, Employment Skills Development, Software Engineering 1
Semester 4	Professional Industrial Placement

Appendix 2 Model 1 outline structure

Working title **FdSc Mathematics with Business**.

	Modelling (1)	Mathematics and Statistics			Business	
Year 1	Mathematical Modelling 1 (2)	Mathematical Methods 1		Statistics and Probability	New Venture Creation	Understanding Organisations
Year 2	Mathematical Modelling 2 (2)	Mathematical Methods 2	Maths for Finance and Business	Statistical Methods	Managing Business Finance	Managing for Performance
Year 3	Advanced Modelling (2)	Mathematical or Statistical option (e.g. Statistics for Business)	Project	Professional Development (2)	Business option (eg Supporting Entrepreneurial Ventures)	Business option (eg Strategy and Change Management)
(1) Solving real-world problems using mathematical and statistical approaches						
(2) To incorporate work-based learning						

Appendix 3 Consultation over Model 1 via SEMTA

We present in this Appendix a copy of the questions we asked in our short consultation questionnaire as presented to SEMTA.

Summary

We would like to hear your views on the feasibility, usefulness, demand and desirable modes of operation of an FdSc foundation degree with significant, practical mathematical and statistical content combined with wider skills development.

In this paper we offer an outline proposal, and we would be grateful if you could answer the small number of questions below, and return your response preferably by 18/12/2008.

This initiative is just one part of the HEFCE More Maths Grads project, which aims both to increase and to widen participation in courses with significant mathematical content.

Background

We are investigating the demand for upskilling members of the workforce by improving their competence in numerical and other work-related (including IT) skills, and considering whether this can at least in part be addressed through FdSc Foundation degree provision involving the mathematical sciences.

This is part of the HEFCE-funded More Maths Grads project, which aims both to increase and to widen participation in courses with significant mathematical content.

Nature of and demand for such a course

We are proposing a course which aims to make its students:

- highly numerate;
- skilled in the use of commonly applicable mathematical and statistical approaches to solving practical problems in business and industry;
- skilled in the use of technology, both for everyday purposes and to implement mathematical and statistical approaches;
- enterprising, business aware and with well developed key skills such as communication, team-working, self-management, etc.

Question 1

Are you supportive of a course which provides this mix of skills? Would you perceive there to be a potential demand for such a course from yourself as an employer, and from employees in your organisation or from elsewhere? Are there other skills which you believe your employees would benefit from developing through a course such as this?

Question 1 response:

Question 2

Our specific proposal mentions combining the development of mathematical and statistical skills, generic skills and technological know-how with business skills. Would you as an employer see this combination as useful, and/or would you envisage other combinations which your employees would find useful in supporting their development (e.g. developing engineering skills instead of business skills)?

Skill area	**Please score from 1 (no use) to 10 (highly useful)**
Basic numerical and mathematical skills	
Practical Statistical skills	
Problem solving skills	
Oral communication	
Written communication	
Team-working skills	
Business awareness	
Generic IT skills (Windows, Word, Excel, Web etc)	
Specialist IT skills (maths and stats packages)	
Please add your own comments as appropriate:	

Mode of study

We envisage this course being aimed at people who are currently in employment but looking to be upskilled; students must therefore be able to study alongside their normal employment. One proposed mode of study would be distance learning, with students supported by notes and worksheets, by a virtual learning environment such as Elluminate, and with occasional block release and study schools. Alternatively we might consider more traditional part-time study for instance day release and evening attendance.

Question 3

Do you think that offering this as a distance learning course would be attractive to currently employed potential students or to employers (including your own organisation) wishing to upskill their workforce?

Please comment on this and upon other possible modes of study such as full-time or more traditional part-time modes such as day release and evening attendance.

Question 3 response:

Entry qualifications

We propose that the minimum entry qualifications would be:

- AS Level Mathematics, or
- equivalent qualification (academic or vocational), or
- GCSE Mathematics plus a bridging course to be studied before starting the course.

Question 4

How do you think the demand for the course would be affected by entry requirements? Is it realistic to stipulate prior study to AS level equivalent? Would bridging study be viable and attractive?

Question 4 response:

Thank you for your contribution.

7.5 *Making the Transition to Mathematics at University Stimulating*

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Abstract

Many Mathematics departments now spend some time in their first year revising basic A-level material. A problem is to provide this revision and expand the tools learnt as routines at school in a stimulating way that promotes the development of advanced mathematical thinking. This case study describes a Transition Module that pays careful attention to the way elementary topics are revised and how they can be used to encourage higher order learning skills and provide stimulating examples.

Background

The 'transition problem' has been tackled by diagnostic testing, computer assisted learning, mathematics support centres, peer tutoring and so on. However, less has been done on the actual teaching and content of the curriculum. The responses to these are usually confined to diluting the content or focusing on improving facility levels. Valuable though this is, it reaffirms the routine nature of mathematics as learnt at school, and it offers little new but consolidation of vaguely remembered material, when we can at the same time:

- treat this elementary mathematics from an advanced viewpoint, giving tasters of how it is used 'down the line'
- emphasize the history, utility and importance of the key topics
- provide an overview to how the different topics link together and their significance in a wider context
- emphasise the importance of remembering the key basics and using higher mathematical skills to develop the details

This case study describes some of the methods used in this way.

Implementation

The Transition Module at Aston is aimed at consolidating core A-level material with predominately A and B grade students. Topics are revised in a way that encourages higher order learning skills for advanced mathematics, and an appreciation of their significance and importance. This requires a considered treatment of apparently mundane material, a treatment of advanced mathematics from an elementary standpoint, an overview of where the topics lead, and an emphasis on remembering the fundamentals well and using higher order skills to develop the details and generalisations.

By analysing the profile of incoming students (spread of A-level grades, etc) the main areas for revision can be identified [1] – for example even with higher A-level grades one needs to revisit such topics as completing the square, Binomial Theorem, the exponential function, series, trig identities and equations, facility with differentiation and integration. The manipulative aspects of such things can be dealt with by copious exercises to develop facility and speed. The module has a book website that fulfils this purpose [2]. Then we expand these topics and emphasize their importance in later mathematics and its applications. This in itself provides practice in the routine skills, but in a richer context. We will illustrate the approach with a couple of examples.

Completing the square

Most pupils are taught completing the square en route to solving quadratics. They invariably therefore confuse completing the square of a quadratic **function** with solving a quadratic **equation**. This is an instance where the difficulty is getting them to unlearn inherited misconceptions, in this case confusion between expressions and equations. They also have difficulty remembering the procedure itself and this is usually because their facility in the key points of the procedure is so poor that they are in themselves a hurdle. So $(x+a)^2 = x^2 + 2ax + a^2$ for example has to become second nature. They also need to understand the use of $A - A = 0$ to convert to the perfect square and at the same time learn that this is a standard ploy in mathematics, along with similar replacements such as $\frac{A}{A} = 1.$

So here they are learning that high facility is needed with basic skills, and that sometimes changing the form of an expression can render its properties more transparent, both highly transferable skills in mathematics. The learning of the actual technique of completing the square is almost incidental to the development of these broader skills.

Another barrier to learning completing the square is its apparent lack of interest apart from helping us to solve a quadratic. Many students appreciate that in the completed square form the stationary point is obvious, but are not aware that from this the general stationary conditions for any function can be derived. Thus, near to a turning point any well behaved function can be approximated by a quadratic truncation of a series (One can develop this as an example of expansion in a series, determining the coefficients by differentiation, thereby introducing power series). We can then derive algebraically the condition and location for the turning point of any such function. The algebra for this is quite involved, providing practice in the sort of lengthy manipulation in which advanced maths abounds.

Later on in their studies completing the square will go into higher dimensions in diagonalising matrices, stationary points of functions of more than one variable, etc. The point here is that completing the square is not just an ad hoc technique used in solving quadratic equations. It has ramifications far beyond that, and is built up by a number of key skills and ideas that pervade mathematics. One can also discuss its history, its geometrical aspects and so on. In this way we are turning a routine revision chore into a motivational aid and a tool for developing advanced mathematical thinking.

Trig identities

Talking of chores, the formulae book presentation of trig identities at school level robs them of most of their interest. The students see no need to commit any of them to memory and believe them all to be equally (un)important and uninspiring. But they are vital and in fact contain a large number of teaching points of great interest. Firstly, so far as the sinusoidal functions are concerned we only need two:

$$\cos^2 x + \sin^2 x = 1$$

$$\sin(A+B) = \sin A \cos B + \cos A \sin B$$

The first is of course Pythagoras' theorem thinly disguised, and it is difficult to imagine a more important result in mathematics or physics (In further mathematics it gives us the metric concept, in general relativity it generalises to the metric which describes gravity, in quantum mechanics it gives the probability density function for the value of any physical property, etc). The second is the compound angle formula, which has an interesting history in converting products to sums, before the invention of logs. Students are expected to remember these two identities only, but extremely well, so they can derive the rest of the trig identities themselves, or at least are aware of their existence. The lessons learned here are that underlying many apparently featureless and unconnected results are often just a couple of fundamental results requiring instant recall from which the rest follow.

Then we can get the students to think about why these two identities are key, why do they yield all the rest? We can point out that the compound angle formula has the functional form

$$f(x+y) = f(x)\sqrt{1-f^2(y)} + f(y)\sqrt{1-f^2(x)}$$

the solution of which, to yield , is well within the skills of the A-level student, but it has the added advantage that it reinforces function notation to students who often have trouble with it – it also employs and revises elementary calculus [4].

Of course the two identities $f(x) = \sin x$ given above are all that are needed to derive the result . The reason we use this result is the same as that for completing the square – to render the properties of the function more transparent - once again reinforcing a valuable transferable skill of mathematics. As a topical example it explains why it is colder in February than in December – the combination of the two sinusoidal variations of $a\cos x + b\sin x = R\sin(x+A)$ earth's temperature with the heat from the sun produces, by this result, a phase shift of two months (I am grateful to Chris Budd (Bath University) for this example). There is also a nice example from one of the most important areas in the foundations of quantum theory combining trig identities and completing the square [3].

Again the point of this example is that we have turned a mundane exercise of revising trig formulae into an interesting piece of mathematics with lots of useful teaching points and transferable mathematical skills.

The examples above illustrate the main point that the essential revision of school material can be much more than consolidating the basic techniques, it can enliven the topics by giving them an advanced slant, it can emphasise unsuspected importance, and it can be used as a vehicle for developing important advanced mathematical thinking skills. There are numerous examples where the school level emphasis on techniques denies the student global overviews and key insights into the structure and connectivity of mathematics. By opening their eyes to such things we can make the chore of revising basic skills stimulating and informative.

Barriers

1. x Obviously, such an approach makes the teaching more difficult, the teacher has to have a broad and deep knowledge of the material, its significance, and its history. They will need to seek out examples of further use of the material in their curriculum, and be able to explain advanced ideas from an elementary standpoint (The popular science bookshelves creak with books that can be mined for such examples). There is also a tension between the skills one seeks to develop. One is essentially seeking to develop high facility levels with the basic material. This needs to be balanced, in the curriculum and assessment, against the more interesting desire to deliver higher order skills and provide high levels of motivation and interest.

Enablers

The approach also makes it more interesting. This type of revision class is not the most popular teaching assignment, but treated in the way described it can be stimulating for the lecturer too. It can also be informative – thinking in depth about some elementary topic can sometimes give one ideas useful in other contexts, perhaps your research. Also, while many modules are relatively prescribed in their content so motivational diversions are limited, the sort of revision module described here has more slack and provides many opportunities for exploring interesting topics in breadth and depth.

Evidence of success (impact)

It is difficult to give evidence of impact of this approach. Student feedback scores on interest of the material are usually high, and in later years students exhibit appreciation of topics which they have previously met from an elementary viewpoint. Also, the assessment is geared mainly to testing use of the basic material rather than recall (facility is tested through speed, absence of formula sheets, a compulsory section on the exam, etc), and students perform well in this. But perhaps it should be self-evident that making routine revision material stimulating and instructive is a virtue in itself.

Quality assurance

This module is subject to the usual University and departmental quality assurance mechanisms.

Recommendations for others

Anyone adopting such an approach will have their own ideas about specific examples, but the basic principles will be the same:

- dentifying and emphasising the absolutely fundamental topics which pervade future mathematics in the degree programme
- Providing ‘mini-projects’ related to further developments and topical stimulating examples
- Setting the topics in a broader context and giving a range of developments and applications
- Using such developments to provide practice in the basic routine skills
- Emphasising the importance of high facility levels as a foundation for higher order skills
- Posing intriguing questions and giving surprising answers

Other

As a general point, we are sometimes caught in the ‘snare of coverage’, with the desire to develop technical skills and getting students to be able to do things (Mathematics is undeniably a doing subject). But this should not stop us thinking of ways to stimulate them and to develop higher order thinking skills [3].

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7.6 *Essential Mathematics*

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Abstract

The Essential Mathematics initiative has addressed successfully a difficult problem: an alarming number of mathematics students reach university with inadequate basic skills in elementary arithmetic and algebra. This programme has been running for nearly a decade at the School of Mathematical Sciences, Queen Mary, University of London. Essential Mathematics is based on the principle of no compromise on minimal standards for basic skills. It relies on a vigorous assessment method, transparent quality assurance, and web-based teaching material.

1. The problem

In continental Europe, a 12-year old student is normally expected to handle arithmetical expressions such as[1]

$$\frac{1}{6}+\left[\frac{5}{21}\div\left(1+\frac{7}{3}\right)+\left(-\frac{1}{2}-\frac{4}{7}\right)\times\left(\frac{2}{4}-\frac{4}{5}\right)\right]\div-\frac{2}{5}\times\left(1-\frac{1}{4}\right)$$

and at age 13 algebraic expressions such as

$$y\left[\frac{1}{2}x\left(2x-\frac{4}{3}y\right)-\left(x+\frac{1}{3}y\right)^2\right]\div\left[\left(x-\frac{1}{3}y\right)\left(x+\frac{1}{3}y\right)-x^2\right]$$

Similar expectations are found elsewhere, for instance in south-east Asia.

By contrast, only a minority of British students are exposed to such a level of computational complexity, even among those who specialise in mathematics. The roots of this problem are deep and complex; the result is a dramatic lack of fluency, stamina and confidence in basic manipulations, whose repercussions are felt across the entire curriculum. These deficiencies undermine the understanding of advanced constructs, deprive the students of a vital support for abstraction and limit their ability to use computers effectively. Above all, too many students are denied the pleasure of doing calculations.

Currently, a student can sail through mathematics A-levels without this problem being detected. Universities must therefore assume a new responsibility. Yet there is a straightforward solution: to have the students do lots of exercises. The difficulty lies in persuading a beginning university student to engage in an activity which seems unglamorous and unrelated to higher mathematics (it is neither), and where the time scales for reward are invariably long.

2. The initiative

The Essential Mathematics (EM) initiative – arguably, the most vigorous in the UK – was introduced in the academic year 2001/02, along with the supporting course Essential Mathematical Skills. Its success motivated the introduction, in 2004, of the twin course Essential Foundation Mathematics for the Science and Engineering Foundation Programme.

The EM programme is designed for a large student population, currently over 250. Its main ingredients are:

- high expectations
- transparent procedures
- web-based learning material.

To be admitted to the second year, all Queen Mary students with Mathematics as home department must pass an examination on basic arithmetic and algebra (integers, fractions, square roots, polynomials, rational functions, linear and quadratic equations). This scheme was introduced following two failed attempts to embed remedial work within a first semester module. These attempts were either ineffective, or resulted in unacceptably high failure rates.

[1] From a textbook for the Italian national curriculum, 1996.

The EM exam has little in common with the other examinations. It is offered seven times during the first academic year, and it must be taken repeatedly until passed; students who do not pass do not progress to the second year, irrespective of their performance in all other first year modules. The EM exam does not count towards the final degree, but it appears in the students' transcripts.

The exam is substantial, with pass mark at 80%. The level of difficulty is determined by absolute criteria, not by considerations on progression. The exam adopts a pass/fail multiple-choice format, with 15 questions, and 12 correct answers to pass. Such a sharp pass/fail criterion is essential, given the uncompromising nature of the scheme. The exam is predictable, and questions never change in contents or style: only the numbers change. Two sample exam questions are displayed below.

1. Compute $f(-1/3Y)$, where

$$f(b) = 6b - \frac{1}{3b^2} - \frac{1-b}{9b^3}$$

[a] $\frac{3Y^4+4Y^3-2}{Y}$ [b] $-\frac{3Y^4+4Y^3+2}{Y}$

[c] $3Y^3 - 4Y^2 - \frac{2}{Y}$ [d] $3Y^3 - 2Y^2 - \frac{2}{Y}$ [e] not in the list

2. Simplify, eliminating radicals in the denominator

$$\frac{1}{7+3\sqrt{5}} - \frac{30}{\sqrt{20}}$$

[a] $\frac{7-15\sqrt{5}}{4}$ [b] $\frac{7-9\sqrt{5}}{4}$

[c] $\frac{7+9\sqrt{5}}{4}$ [d] $\frac{14-15\sqrt{5}}{8}$ [e] not in the list

The *quality assurance* of this examination is based on *total openness*, rather than on *certification*. As a result, the examination bureaucracy is virtually non-existent. The students get to know the exam results before they leave the examination room, and retain a copy of their submission for their own record. There is no stigma attached to failure. The examination process is open to inspection: past exam papers with answers are posted on the web, and so are the examination statistics. Abundance of examination opportunities and deterministic marking eliminate many burdens of examining, such as the need for blind marking, agonising on the pass/fail borderline, or handling extenuating circumstances or appeals. Because any mistake in the exam would become public, we implement a rigorous procedure for checking the correctness of the examination paper. The examiners have no discretion at their disposal, so the external examiner's role becomes largely irrelevant.

The students attend a presentation of the programme during induction week. They are then given two weeks to get acquainted with the syllabus and the web-book (see section 4), to attempt mock exams, and to seek help from their advisers. Then they sit the first exam, which has no surprise element in it, and for which they are given plenty of time: two hours. Most students fail it (see below), and are hence enrolled in the supporting course, which runs alongside the other first semester courses. This is a complex operation, with several parallel tutorial sessions of approximately 20 students each, complemented by weekly tests on the material being covered. The course is partially supported by the Widening Participation programme at Queen Mary, which provide some of the teaching. All teaching material is available on the web (see below), and self-study is strongly encouraged. Staff are needed to identify the weakest students, to coordinate support activities (of which the peer support programme PASS is a recent addition), and to organise action against absenteeism from classes and tests, which are compulsory. The course is repeated in the second semester, for those who have not managed to pass by the beginning of January.

The implementation of the programme has required a substantial initial investment, and a running cost comparable to that of a first-year module. The design of multiple-choice examinations has been laborious; over a period of several years, we built a database of exam questions, equivalent to approximately 30 exams. Most assessment material is now composed from such database questions. Support classes must be sufficiently small in size to allow close supervision. Our crowded first semester timetable leaves little flexibility, so parallel sessions are unavoidable. This in turn requires several teachers, and suitable lecture rooms.

Essential Mathematics was praised as being 'courageous' in a past Teaching Quality Assessment exercise. It has been praised by the externals, and it was briefly reported by the Times Higher Education Supplement (THES) on 28/06/02.

3. The results

The results speak for themselves. During the first few years of implementation, on average, well over 90% of the students failed the first exam, but eventually, over 90% of them passed (Figure 1). These data refer to a student population with (nominally) a B in A-level mathematics, although many students were recruited during clearing.

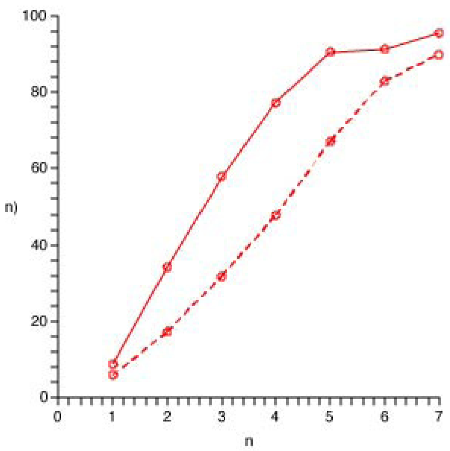

Figure 1:
Cumulative percentage progression in EM exams. Exam 1 takes place in October of the first year, exam 7 the following August. The dotted curve represents an average over the three academic years 2001-2003, which include over 400 students. The solid curve refers to the academic year 2004/5. The markedly improved performance is linked to the introduction of compulsory attendance to lectures and tests. The current (2009) failure rate in Exam 1 is 85%, following an improvement in the students' entry qualifications.

After 2005, the entry qualifications of our students began to improve. Currently, roughly half of our intake have an A in A-level mathematics, but the failure rate in the first EM exam remains very high at 85%. It is clear that the underlying deficiencies are deeply rooted, and cannot be remedied by a burst of concentrated effort, even for competent students. The students who pass at the first attempt form a heterogeneous group; students from South-East Asia tend to do well.

Once a quorum of students have passed, progression accelerates. Over two-thirds of the students now pass by the end of the first semester (exam 4, held in early January). Students are encouraged to pass as quickly as possible. Until recently, those who did not pass by January were forced to drop one first year unit, and formally register for EM as a level 0 unit in the second semester. To minimise the number of students losing a first year unit, in the academic year 2004/5 we introduced compulsory attendance to lectures and to weekly tests, which markedly improved the students' performance (figure 1). Over the past two years, we have opted for a softer deterrent to procrastination; whereas the students who pass by January get 100/100 on their course transcript, those who pass at later exams get a bare pass mark: 40/100. Almost invariably, the students who never make it have strong deficiencies elsewhere. However, we've had a handful of students who did not progress solely because of failure in this module; these students usually transfer to another institution. This phenomenon gives credibility to the scheme, and also raises important questions – see section 5.

4. The web-book

The centrepiece of the learning material is the course's web-book, freely available at

<http://www.maths.qmul.ac.uk/~fv/books/em/embook.pdf >

This book is designed for self-study. Besides developing the basic theory, the book contains over one thousand exercises of gradually increasing difficulty, each supplied with answer for immediate feedback. Some difficult exercises, which lie beyond the requirements of the course, are provided to challenge the best students. The book is also sprinkled with references to interesting arithmetical phenomena, to raise the students' interest and curiosity, and to give the teacher material for interaction with the more inquisitive students.

The web-book took several months to produce, and it was initially proof-read by a team of postgraduate students. Over the following years, the book was improved and expanded.

5. Discussion

Let us consider the issue of minimal standards in university degrees, in connection with the EM programme. Given that our graduates will be the teachers of the future generation, what is the minimum a student needs to know in order to graduate?

When spelling out basic graduate attributes, an analogy with the driving test seems pertinent. If we were told that many people fail the driving test at their first attempt, we would be reassured rather than concerned. We wouldn't make the driving test easier just to improve `progression'.

By contrast, the majority of UK university students now pass most exams at their first attempt, including key foundational courses. This is due to a combination of cultural, bureaucratic, and financial reasons. First, high failure rates are equated to poor teaching, not to high standards. Second, a heavy bureaucracy makes the examination process slow and inflexible; it is difficult to design assessment methods able to accommodate repeated failures. Finally, there are stark financial pressures: failing students means loss of income. The resulting conflict of interests is very obvious, yet seldom acknowledged, partly because some key exam procedures (e.g. scaling of marks) remain protected by confidentiality.

To raise minimal standards in a basic skill, we had to design an assessment system that with regards to ethos, practice, and quality assurance, clashed with the current examination culture. Getting it past university regulations was quite laborious. Yet the uncompromising nature of the assessment forced upon us a considerable level of rigour, not only procedural, but also educational. The urgency to improve learning made us place our teaching and supervision under close scrutiny.

Essential Mathematics also makes a clear statement about the value of raising expectations.

If you demand more from your students, they will give you more. According to a study reported by the THES in 2007, the average working week of a UK university student is the shortest in Europe, so there is plenty of scope for raising standards by stretching our students more. At the Essential Mathematics examinations, I found students who had already passed, but asked to be allowed to sit again, just for the challenge of improving their score, or "to check if I'm still fit". (In one exam, these students accounted for 10% of the candidates!) This unexpected phenomenon gives us an opportunity for reflection.

7.7 *Teaching how to think like a mathematician: writing mathematics*

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Abstract

Writing well is an important transferable skill that is a traditional weakness for mathematics students. I explain how I approach teaching writing that encourages mathematical thinking. This has been successful and is something that any lecturer can attempt.

Background

A common myth is that mathematics teaches critical thinking, or in another variant, logical thinking. The evidence for this seems rather thin. An argument often advanced by lecturers is that they learned logical thinking by 'osmosis' from doing mathematics and so it is sufficient to expose students to mathematics to ensure the same. Experience shows, however, that exposure to mathematics does not necessarily produce a magical transformation of students into logical thinkers. This is perhaps not surprising as lecturers are atypical students - they became research mathematicians. The overwhelming majority of students, even at the highest institutions, do not become mathematics lecturers.

My approach to teaching critical thinking can be seen in my book How to Think Like a Mathematician [1]. Students are encouraged to ask themselves questions as they study. For example, given a statement, they should ask "What is the converse?" and "Is it true?" and "Where are the assumptions used in the proof?" These provide useful starting points for understanding.

The first step to logical thinking is not to give students a course in propositional logic ($p \wedge q \rightarrow p$ and all that) but to ensure that they write mathematics correctly. This may seem counterintuitive. Should we not ensure that they understand first and in later years insist that they write clearly? I believe not. Understanding and writing go hand in hand and good writing leads to an improvement in thinking.

There are a number of reasons to concentrate on writing:

i. Writing is a transferable skill.

ii. Improving writing skills eases the transition to university.

iii. To write clearly, students need to think clearly.

A good university education prepares a student for life and does not just fill their head with the facts of the subject. Writing well is an extremely useful skill for students as their chosen careers will likely involve producing written documents and arguing a case. Many students choose to study mathematics precisely because they do not like writing essays. Teaching writing is therefore essential. On the positive side, even a small amount of effort in this area can lead to a major boost for an individual student.

Improving the writing skills of students eases the transition to university. This is because university level mathematics is much more about understanding and creating coherent arguments whereas pre-university level is more about techniques, for example, finding the derivative of a function. Furthermore, insisting that students write clearly signals to them that the structure of arguments is important, just getting the "right" answer is insufficient.

Point (iii) above is crucial to the view that writing develops logical thinking. Obviously, if a student is not thinking clearly about mathematics, then they do not write clearly. A major effect of focussing on writing is that they are forced to think very carefully about how they are expressing themselves and by extension they have to think very carefully about the mathematics behind it. Also, if we allow students to submit a jumble of symbols without an argument, then we send the message that the numerical answer, say, is the important feature and the argument is not. Hence, they will focus on getting the "right" answer rather than making their arguments logical.

Implementation

The University of Leeds is a traditional red brick university in the north of England. The School of Mathematics had an intake in 2009 of 158 Home/EU students and 24 international students (the majority from China). Almost all the home students have A at A level in Mathematics and many have Further Mathematics at A or AS level.

During induction week students are given a booklet called How to Write Mathematics (HTWM) containing the two chapters on writing mathematics from my book and I give a twenty minute talk explaining the important points. A pdf file is freely available at

<http://www.maths.leeds.ac.uk/~khouston/pdffiles/htwm.pdf >.

In their first year, standard BSc/MMath students have weekly tutorials in groups of 6 with pure, applied and statistics tutors (a mix of lecturers and PhD students). Students submit work weekly to their tutors for marking.

The HTWM booklet contains many examples of good writing practice. I tell my tutees that they should begin by concentrating on the following principles.

i. Write in sentences.

ii. Do not abuse the implication symbol.

iii. Equals means equals.

iv. Explain what is an assumption and what is a deduction.

v. Demonstrate that an equation is true by working on the more complicated side and showing that it is the same as the other side

Point (i) may seem obvious but many students do not see the need for sentences. Admittedly, until university, they usually could submit a collection of unconnected symbols and still achieve full marks.

The second point about abuse of the implication symbol is very important as it sends a signal to students about logical precision. Bertrand Russell said that mathematics is about $P \Rightarrow Q$ (but you never ask whether P or Q is true). The starting point for logical thinking is to get $\Rightarrow$ right and so we should be merciless in punishing its misuse. This poor symbol is one of the most overused by students and is pressed into service where it should not be. The belief is that using lots of $\Rightarrow$ symbols makes an argument more mathematical. Common problems include using it at the start of sentence -- many students view it as saying "This is what we do next" -- and using it in place of the equals sign. For example, $\cos(\pi/6) + i \sin(\pi/6) \Rightarrow \sqrt{3}/2 + i/2$.

This brings us to (iii). Students do not always see the equals sign as meaning equal! They see no problem with having a vector on one side of an equation and a number on the other. Another example is induction. Suppose that $P(n)$ is the statement that $\sum_{i=1}^{n} i = \frac{n(n+1)}{2}$. Students will happily write "Assume $P(n)$ is true, then $P(n) = \sum_{i=1}^{n} i = \frac{n(n+1)}{2}$" which betrays that they do not distinguish the statement from the equation. This is of course a subtle point but by being firm in observing that "equals means equals" we force them into the pedantry necessary for mathematics. Another particular problem is that students produce errors by reaching for their calculators and using the resulting approximations in their calculations. Hence, I punish errors like $\sqrt{2}=1.41$.

To stop students seeing mathematics as being exclusively concerned with formulae and equations I tell students to explain what they are doing. For example, explaining what is an assumption and what is a conclusion. In the example from the How to Write Mathematics chapters mentioned earlier, rather than write "$a^2 = (c+x)^2 + h^2$, $a^2 = c^2 + 2cx + h^2 + x^2$, $b^2 = x^2 + h^2$, $a^2 = c^2 + 2cx + b^2$", they should, for example, write "From the diagram we see by Pythagoras' Theorem that $a^2 = (c+x)^2 + h^2 = c^2 + 2cx + h^2 + x^2$ and $b^2 = x^2 + h^2$. By substituting the second equation into the first we deduce that $a^2 = c^2 + 2cx + b^2$." The former is just a collection of symbols. The second is an explanation.

Furthermore, novice students generally do not know that in a proof we should use all the assumptions in the statement (or else the assumption was unnecessary). Drawing their attention to assumptions and deductions in their own work helps solve this problem.

Point (v) is useful as it makes proofs clearer and saves them writing. It also improves mathematical thinking. When showing an equation holds, students often start with the equation and manipulate it until they produce a true statement such as 1=1. As mathematicians we know that assuming what had to be proved is not correct. Insisting they show an equation holds by taking one side and simplifying it we do two things. First, we stop them making logical mistakes. Their usual method can be used to "prove" -1=1: "We have -1=1 implies that $(-1)^2=1^2$ by squaring both sides, since 1=1 the original equation is true!" Second, a common problem for students is that they do not know where to start on a problem. By taking only one side they have simplified their task since they have fewer expressions to work with.

Barriers

Over the years problems were encountered.

a) A lot of initial effort is required as very detailed comments have to be made on students' work. However, this pays off later in the term, their work is much easier to read (and therefore less exhausting!).

b) I often have to write the same comments repeatedly week after week, which can be dispiriting. I ease the burden by referring to the relevant section and page in the HTWM booklet.

c) Students are against writing correctly. They often say things like "I didn't come to university to write essays", "But I got the right answer" or "You know what I meant". Dealing with this requires tact and patience as it takes time for the students to realize that the writing is helping them.

d) Students don't read the feedback. An anecdote shows the problem and an admittedly extreme but successful solution. One of my tutees was apparently not reading my comments as he regularly made the same mistake. To remedy this I wrote on his work that if he did it again, then I would stamp on his work. Sure enough he did not read the comment, made the mistake again so I repeatedly stamped on his work in front of him. He was most surprised and of course had to admit that he never read my comments. His reason was that the numerical mark was the important thing. He also revealed that he knew that by reading the comments he could learn from his mistakes. This is a general problem. Students do know what is good for them. They know they should get up for a 9am lecture and they shouldn't leave revision until the night before. However human nature is against them.

Another answer to this is to not give a mark. This has problems in itself - students want a mark or else they can't judge how well they are doing. (In the UK the National Student Survey asks about quality of feedback and students may view the absence of a numerical grade as poor feedback.)

Enablers

As stated earlier the School of Mathematics gives a copy of the two chapters on writing from my book to the students during induction week. Also, the School trains PhD students in marking work, part of which involves the correct writing of mathematics. This means that students see that the School believes in the importance of writing and it is not just the hobbyhorse of one pedantic lecturer.

Evidence of success and impact

It is difficult to objectively measure the success of teaching writing to improve logical thinking as we never know what a student would have achieved without it. However, I have found that students do become more pedantic and start to see the details of the concepts they are describing. The whole area of writing is under-researched. I suspect that despite its importance it is ignored by lecturers. One solution I heard proposed to the problem of poor writing was "Tell students to write their work so that someone else can understand it". If only it were that simple.

Significant improvements in student writing are easier to see. I make copies of students' submitted work and a huge difference, and hence an impact, is evident by the end of the year.

There is evidence that the lessons learned are retained. While marking an anonymised second year exam I noticed that a weaker student was writing clearly. A later check confirmed my suspicion that the student was an ex-tutee.

Another important measure of success is that although students initially oppose writing clearly, they eventually change their mind and accept its necessity. Quite a number thank me later and say they hated it initially but are glad that they were forced to do it. Various reasons are given, including that it helped clarify for them what they did not understand. Enforcing clear writing is a good example illustrating that we should not give students what they want but give them what they didn't know they wanted.

Recommendations for others

First, I would not advocate introducing a module on writing mathematics. One, there is usually not space in the working week. Two, as in most education, skills should be integrated into existing modules or else they do not transfer well.

I am fortunate that I have only 6 students in a group. For modules with a large number of students it may be impractical to mark all the work to the necessary standard. One can save time by specifying the page number from the booklet. Another method is to produce a handout for all students discussing common problems. This obviously does not deal with problems specific to individuals but has the advantage that students see the mistakes of others.

It is important to be explicit that marks will be gained for good writing. Students are motivated by assessment and will pay little attention to something that does not get marks. We can send powerful signals to students about a subject by attaching marks to it. There is no harm however in pointing out that good writing skills will help them in their careers.

Often when students finally accept the importance of good writing they go to the extreme of writing out everything in great detail and their work becomes very long and unwieldy to mark. This is a good sign. It means they have grasped the importance of writing. Fortunately, it is very easy to rein them in -- they are relieved to write less!

Encouraging good writing requires persistence. I often repeat myself many times and even when the students finally understand, they sometimes return to their old ways after a few weeks. On the other hand, when a student has really "got it", unlike knowing some obscure mathematical fact, this is a skill they can apply in their lives long after they have left my charge. That is surely an activity worth doing.

[1] Houston K (2009)*How to Think Like a Mathematician: A Companion to Undergraduate Mathematics*, Kevin Houston, Cambridge University Press.

7.8 *The Professional Development module at Sheffield Hallam: a case study of explicit introduction of careers awareness into the HE curriculum*

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Students on the BSc Mathematics course at Sheffield Hallam University must take a final year 10 credit module called Professional Development. This module began life as a space where students who had carried out an industrial placement between their second and final years could report and reflect upon their experiences in employment. It has now become an opportunity for placement and non-placement mathematics students to share their experiences and views, and reflect on employment, employability and career development in their future as a mathematics graduate. They address a set of tasks both as individuals and in small groups.

In the group activity, students take on an investigation into roles played, and issues faced by mathematics graduates in post-university life and employment within a particular sector or industry. There is also time for explicit individual reflection upon the student's own state of development and possible futures. This reflective activity can form the early stages of the kind of process increasingly required to maintain professional designations such as Chartered Scientist and Chartered Mathematician.

The Professional Development group investigation into mathematicians in industry

As one part of the Professional Development module then, students are told they must investigate, in small groups, what mathematics graduates do at work, and the skills they require. In particular:

- They investigate the jobs that mathematics graduates actually do. They may look at sources such as the *Prospects* website [1] and the *Mathscareers* website [2] amongst others.
- They carry out research on the skills that employers, and graduates themselves say they value most in mathematical graduates.
- Each group chooses one particular industry. Industries in the past have included amongst others transport, sport, leisure, finance, banking, insurance, engineering, retail, healthcare, and the oil industry. In their chosen industry, they:
    - » research the skills identified as being required by mathematics graduates in that industry;
    - » seek out some specifically mathematical tasks carried out at present in the industry;
    - » report upon some unsolved problems in the industry;
    - » write down current approaches to solving those problems or explain difficulties inherent in solving them;
    - » reflect upon where mathematics could make or is making a contribution to solving the problems;
    - » identify major ethical issues that arise.

Each group presents their findings through a presentation to the rest of the class, and a report. We might note in passing that this is one of a planned series of opportunities students have to practice some of what have become known as employability skills – on this occasion, presenting, report writing, research and information gathering, and perhaps most of all, managing a task in a group.

The role of group work, especially in the final year, is the cause of much discussion and analysis. Students will have experienced group tasks in other years and other modules of their course, and particularly for those who have carried out an industrial placement, they will have experienced the necessity of being able to make the best of the teams in which they inevitably work. The aim here is that students will bring to bear a greater maturity when, as part of this module, they reflect individually and in a structured way upon how well their group functioned, and submit their reflections as one part of a portfolio of work on the module.

It presents an interesting dilemma, that experiencing group work allows students to develop their employability, and at a base level gives them something to refer to in their job applications and at interview; but if this component comprises too large a part of the module mark, particularly at final year, then it is seen as undermining the validity of the degree result. Our view is that one quarter of a 10 credit module is acceptable. That perhaps does not reflect the proportion of effort required for this task, but to give it any higher proportion would indeed be seen as being potentially too influential on the degree classification.

How students have responded to the group activity

In the most recent year, there were 9 groups of about 5 students each. The “industries” the students chose for themselves within their groups were banking and finance (2), just finance, insurance, meteorology, education, medicine, pharmaceuticals and engineering. Perhaps given the first destination data from Prospects, these choices are not surprising, but worthy of note is the variation in scope between different choices, from all of banking and finance, or all of engineering, to the relatively focussed meteorology.

The students researched skills, qualities and attitudes required by mathematics graduates mainly by visiting a variety of websites. These included company websites (e.g. particular banks) where in some cases graduate training schemes are mentioned, job vacancy sites and graduate careers sites from various universities, as well as the Prospects site. This process allows discussion about research skills, for instance considering whether one trusts a company’s own website more or less than Wikipedia’s unmoderated but independent website.

Some groups simply provided a collated list of skills and qualities gathered from a wide variety of documents or websites, others went to job advertisements and took what they said they required at face value. In some cases skills were mixed with qualifications, for example one group identified a “skill” as being in possession of at least a 2ii! Lists included the usual suspects: communication, problem solving and modelling, group-working, self-motivation. It is frequently averred that mathematics graduates are especially valuable because of their ability to think logically, rationally and analytically as they approach a problem to be solved. It is perhaps a little surprising that only four of the reports identified that as a distinguishing feature. It is also interesting that they almost take for granted what mathematical skills they have met or would need. The meteorology group identified more specifically mathematical skills, but other groups on the whole identified only general skills. This may reflect the commonly stated desire of many employers to employ rounded graduates well versed in “employability” skills, and in this respect it may reflect the fact that in many, perhaps most instances, mathematics graduates are in competition with graduates from other disciplines for jobs which are not specifically mathematical. It may also reflect the nature of the particular course these students are taking, which lies firmly at the “practical” end of the mathematics, statistics and operational research benchmark spectrum, and sets great store by making explicit to students how they are developing their employability in a general sense.

There is a discussion to be had here about whether we all mean the same when we use the phrase “problem solving”. That which we may call a problem sheet on a mathematics course is sometimes a set of rote practice examples – “I’ve done one, now you do some”. In an industrial context, problem solving may involve complex real world problems, with a range of practical, theoretical and human dimensions. However, even, or perhaps especially, in that case, one might hope that a clear thinking, analytical and rational approach would be valued, even if any particular mathematical technique may only be tangentially useful.

The list of issues that the student groups raised as they addressed the questions around the way mathematics is and may be useful in their chosen industries is of course not comprehensive, given the relatively modest weighting of this task, and the marker can look forward to being surprised and amused by the choices made. For instance in the group which addressed the engineering industry, while students realised that mathematics is ubiquitous in engineering, they wanted to choose particular areas that interested them. The first area identified included computer consciousness and modelling the human brain (under the heading of software engineering); and the second was the rather more traditional civil engineer’s task of modelling vibrations in bridges.

Modelling was of course almost universally mentioned, for instance financial models, flow models, epidemic models, and ecological models, and the importance of statistical and stochastic approaches was recognised. We might note in passing that some problems identified – for example moral hazard and mis-selling in insurance, or the credit crunch – may perhaps require mathematics to join hands with moral philosophy before a solution may be reached!

The students turned out in general to be keenly aware of the impact of ethical considerations upon decisions about where to seek employment. For example, one report said, *“you do not want to join a company which you then later find out has policies that conflict with your own morals and values.”* Ethical considerations are part of careers awareness. While in narrow terms one may perceive mathematics per se as value-neutral, this group of students realised that mathematically qualified people, whether applying mathematics or not in a wicked world, face all the choices and dilemmas that other people do. It seems that mathematicians are people too.

Other aspects of the module

Elsewhere in the module, students submit individual work. They reflect upon how well or otherwise the group work went, rather than just suffering it and being grumpy about it, and therefore it becomes a credited learning experience. They may be supported in this by tools such as the Belbin team role questionnaire [3]. They explicitly reflect in writing upon their own progress on the course and beyond with a view to their developing awareness of what may come next. They perform simulated job application work including dummy interview work. In some cases this goes beyond simulation to become a live application; in others, students may use the practice application for just that, for instance in some cases doing a simulated application to a bank, but actually finishing up applying to be, and becoming a trainee teacher.

What do students get out of it?

It is not simple to generalise what students get out of this process, measured against the stated aims of reviewing, reflecting on and improving their range of skills, making informed choices about and developing a strategy and plan for developing their preferred career direction, and researching and debating a range of professional and ethical issues related to employment in their discipline. A few individual cases will give some flavour of what happens.

Student A did a one year placement as a statistical programmer; she has realised that some, although not all, companies filter their applicants by A level results as well as degree classification, and did a dummy application for a graduate statistical programmer job. She carried out a deep analysis of group work using the Belbin team roles methodology, showing herself capable of working and thinking in a mature and self-critical way. She progressed to do an MSc course in Statistics, with the aim of working in pharmaceuticals. She said, as part of her extensive reflection, *"The module has allowed me to reflect on my weaknesses/strengths and has given me motivation to apply for postgraduate courses. Reflection is a very important part of improving; you cannot improve if you haven't reflected on why you may not be good at something."*

Student B did not do a placement. She did a dummy application to a bank's graduate leadership programme but also realized she was excluded from some online application forms because she did not satisfy criteria on A Level grades. She also carried out a deep analysis of her group work experience using the Belbin methodology. She progressed to a secondary mathematics PGCE course – which had been her intention for some time. *"Although this module has not explored the area of mathematics teaching this is still a career I would like"*. Her explorations through the module confirmed her in her original feelings.

Not all students were so well organized. Student C did not do a placement; his account of how his group functioned was unsupported by any framework, and was descriptive rather than analytical. While he identified computer and web programming as an area of interest, the reflection was restricted to how well he was or was not coping with the demands of the final year of the course. Of course perhaps one should be pleased if the reflection helps this student to gain control of his workload and learning and therefore to stand a better chance of succeeding on the course (he did!)

In spite of their differing levels of analysis, all three students mentioned so far displayed significant honesty and a developing self-knowledge, and knew what they needed to do to achieve their aims, albeit that in cases A and B, those aims saw further into the future. For instance A identified a continuing need to work on writing skills, to broaden both programming and statistical knowledge, and to find out more about eventual employers of statisticians. B identified a need to work on interview skills and confidence.

In two cases quoted here then, a definite sense of direction was achieved. In the third, an interest and a possibility were identified. This was not so in all cases. A fourth student, Student D, presented a bravely honest reflection on how his writing skills had improved in spite of his course being in mathematics, how he needed to be more confident in presentations, and how he gained much enjoyment from the ethical aspect of his group work, all useful insights in enhancing employability. However he wrote, *"My main weakness in this module I believe is my inability to plan for the future. I really don't know what I'm doing after I leave University."* It seems that achieving greater careers awareness is not synonymous with achieving certainty about your future aims.

Reflection on the Professional Development module

The Professional Development module represents one way in which some careers awareness is being brought into a Mathematics degree, allowing time for students to reflect upon and tackle some of the issues they must face, but maintaining some degree of focus on the fact that this is a mathematics course. This format may not suit all courses, but perhaps it is useful to discuss some of the issues raised.

A question may remain as to whether this is a valid use of curriculum time on a course which is, after all, about mathematics. In this particular case, our course rhetoric says that doing a mathematics degree improves your job and career prospects, and this is one part of a strategy for making explicit how we can help that to happen. Is it our job as maths academics to develop careers awareness in this explicit way, or should it be extra-curricular? Our answer to that question at Sheffield Hallam is evident, and the way is cleared by an institutional ethos which values employability. We tell our students before they come that this course will make them more employable; we look at what employers say they want from graduates, and we try to help our students to come to terms with that, at the same time as educating our students mathematically, and passing on our enthusiasm for mathematics. What would the alternative be? We could simply leave it to the careers service or to individuals, but we are the people who have the educational relationship with the students, and we are able to show we take an interest in our students' futures and care about them as our course rhetoric says we do, and we can give value to these activities by giving credit.

We did of course question at the design stage, and continue to question, whether this activity has to be in the final year. Students do spend time on developing their general employability skills in years 1 and 2, and all go through a process of review in deciding whether or not to carry out a work placement, but no more than about 25% decide to do that. It also seems that the kind of reflection we are demanding requires a certain level not only of maturity, but also of timeliness in that all students are approaching the end of their first degree, which adds a little more urgency.

There are some challenges for both students and staff. Many students must continue to face up to their shortcomings with written English, with research skills, with referencing, and with presentations, in spite of the fact that they have had previous opportunities to practice, and to receive advice and feedback, for instance through having to provide reports or presentations in modules such as Mathematical Modelling. Usefully, this module occurs at the same time as the early stages of a final year project module which all students take, and practice and feedback from here can help improve standard of project activity and outputs.

Academic markers face challenges in marking discursive material. In spite of attempts to pin down the marking criteria, with proportions allocated under headings such as amount of content, relevance, accurate use of language, sound referencing, etc, one may still be left with a feeling of discomfort when one is used to clear mathematical marking schemes. A strong element of double marking and cross-moderation is inevitable and that can stretch resources.

The main requirement for overcoming these challenges is that the teaching team presents a united positive view of the value of these activities. Whilst, in informal conversation in the early stages students will often decry this module, using phrases like "what's the point?", they do eventually generally accept its value. One student wrote at the end of it,

> *"I believe this module has allowed me to develop the greatest out of all the modules in my third year ... I feel after completing this module that I have a greater insight into my career options".*

References

[1] Prospects, last accessed 14 Dec 2009 at url <http://www.prospects.ac.uk/>

[2] Mathscareers, last accessed 14 Dec 20009 at url <http://www.mathscareers.org.uk>

[3] Belbin, last accessed 14 Dec 2009 at url <http://www.belbin.com/ >

7.9 *Maths, Skills and Employability – an integrative use of group projects*

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Abstract

Connecting academic study and skills development is a growing issue for the transition between Higher Education and employment. An emphasis on lectures, problem workshops and assessment dominated by examination provides well for maths subject-specific understanding and skills but increasing requirements from funding bodies and students' expectations is on employability and career progression of graduates. The potential wide career opportunities are recognised for Maths graduates provided they also have associate skills and attributes to meet demands of employers in a competitive global market. This emphasis encourages extending learning outcomes for mathematics degree students, many of which can be delivered effectively through innovative integrative group project activities.

Background

Skills development within an HE degree is emerging as a high-priority area, the Smith Report [1] in particular draws attention to the lack of awareness of the importance of mathematical skills for future career options and advancement. A series of reports to the Treasury (see [2], [3]) highlights mismatches between the skills of graduates and the skills required by employers. An extensive report [4] by the Royal Society identifies the wide-range of career destinations for Science, Technology and Mathematics (STM) students and the widespread concerns on the provision of skilled graduates to the UK. In a companion report [5], addressing 'fit-for-purpose' for the next decade, it is reported "that in HE we must equip students individually with the knowledge, skills and aptitudes to hold their own with the best in the world".

Explicit recognition of the importance of harmonising skills development within recent QAA qualifications (FHEQ, 2008, [6]), which at level 6 (BSc degree) includes:

- apply the methods and techniques that they have learned to review, consolidate, extend and apply their knowledge and understanding, and to initiate and carry out projects;
- communicate information, ideas, problems and solutions to both specialist and non-specialist audiences.
- the qualities and transferable skills necessary for employment …

Significant project-based activities can be used to extend the understanding and application of knowledge gained from traditional lecture-based methods, but a survey shows this is not universal [7]. Group project activities are even less well embedded in the curriculum despite significant advantages, particularly in skills development.

Implementation of a group project module

Vocational Mathematics is a synoptic module bringing together the subject-specific knowledge and mathematical skills attained in initial years of a mathematics degree in tandem with developing the wider skills expected for graduate careers or higher degrees. Development workshops give exposure to skills awareness and group project activities and projects promote attainment of a wide range of skills including organisation and delegation, project management, team working together with addressing unseen problems and open-ended analysis to tight deadlines. Tasks require background research, selecting and applying mathematical techniques to obtain results and integrating the use of mathematical and presentational software for ultimately communicating quantitative ideas orally and in compact reports.

Students experience an emphasis on:

- working collectively in a non-lecture environment;
- problem solving with a variety of directions and approaches;
- applying acquired mathematical techniques and their communication;
- experiencing first-hand applications of team skills.

Pedagogic advantages include

- students can learn from each other;
- group project activities increases the scope of projects and outcomes to a high level.
- shorter sequential projects gives students the experience to improve from feedback;
- students experience the demands/dynamics of teamwork on a substantial level and also self/peer evaluation;

Benefits are also shared by teaching staff through:

- effective use of staff and student time.
- more student-led activity and active skills learning;
- high quality outcomes.

Workshops provide formal briefings, supporting information, discussion, group activities, and professional videos to develop:

i) Group and Team skills

An introductory 'ice-breaker' activity is used to initiate group working in a competitive challenge. A personal favourite is requiring student groups to build the tallest tower, capable of supporting a given object, from a pile of newspapers in ten minutes. Students typically pass different states of activity from planning to panic; the task separates cautious to wildly optimistic tower modellers. These experiences are captured by student 'observers' who give plenary feedback from each group. Experiencing the requirement to deliver in a tight timeframe in an unexpected task and recognition of different group approaches makes students more receptive to understanding the concepts of group skills. This is followed-up with briefing materials.

An awareness of characteristics of teams is crucial to its effectiveness. Members can contribute in drawing on their technical knowledge but also have a potentially valuable team-role to perform. Employers often look to acquire reliable data for effective team-building from psychometric tests, role play activities, appraisal interviews. Awareness of team roles is explored based on the work of Belbin [8].

ii) Graduate skills

Within this section we explore the rationale for employing graduates. What are the general attributes and specific skills expected by potential employers from (mathematics) graduates? An initial activity is for groups to consider in succession a) key skills expected by employers in graduate employees and b) related key skills they have attained from their degree course.

In practice, the students are dealing with their perceptions and are generally unaware of the skills they attain from a Maths Programme. As an example Table 1 shows average results for the last three cohorts.

Key skills	Verbal communication	Written communication	Problem solving	Teamwork	Numeracy	IT	Self-management	Learning	Technical knowledge
a) employers	24 %	5%	14%	27%	1%	3%	15%	7%	4%
b) graduates	9%	10%	16%	11%	12%	5%	15%	16%	6%

Table 1
Student perceptions of skills required by employers and obtained by graduates

Interpretation identifies what is generally considered a 'skills gap' between graduates and requirements of employers. Students identify shortfalls in verbal communication, and teamwork but erroneously identify greater than expected capabilities in learning and written communications. The wider attributes of graduates are explored in more depth in [9] and the employers' perspective on skills requirements in [10].

iii) Career skills

Mathematics graduates have a wide range of career opportunities open to them but many do not seem to recognise this strength or look to realise the potential - possibly because few employment opportunities have a job title 'mathematician'. A recent CETL project at Nottingham [11] looked at enhancing career skills through groups investigating a financial career path. A skills audit, with a metric of impact, gave high importance to researching careers information (82% impact), career planning (89% impact) and occupational knowledge (89% impact). This framed a Vocational Mathematics task for groups to "research" a designated area of employment. The task requires each group to provide an informative flyer and provide a five minute overview of their findings and respond to questions; the leaflets are shared to all module members as a resource.

iv) Project skills

Importantly, the module is strongly rooted in mathematical modelling, i.e. how to apply mathematics and how to communicate findings. Elements of modelling are almost always included within earlier core modules but group activities enable greater exploration of competing models or wider evaluation. A framework for modelling is provided in [12] and numerous texts provide a source for interesting and diverse examples.

v) Information skills

Obtaining, assessing and researching relevant background information is an essential part of any study. The wealth of sources available is now phenomenal and possibly overwhelming. Within a hands-on workshop session, Faculty specialist library staff takes students through skills needed for effective searches, caution and selectivity on web resources and plagiarism.

vi) Integrated IT skills

During the module students will need to access a variety of information technology resources to help with mathematical computations and also to word-process project reports and to prepare and display materials for oral presentations. Experience is that most students are proficient with use of such products, with the possible exception of dealing with equations, and links to on-line tutorials is sufficient. Access to specialist mathematical software is standard and builds on learning from prior core modules.

vii) Presentations

Students have extensive experience of sitting through academic presentations; as a first exercise a group activity is for each student group to compile a list of "do's" and "don'ts" for effective presentations. A compilation of recent student responses is given in Table 2. A plenary Session then brings together these points and allows further discussion. Training support for students is provided by general and subject specific materials, professional video and also access and discussion from previous project presentations.

Do's - What do you rate as positive in an oral presentation		*Dont's – What aspects of oral presentations should be minimised or eliminated*	
speak clearly	set out structure	just read from slides	repetition
good timing	stick to objectives	use jargon	long pauses
confidence	prepare slides	panic	bad humour
engage with audience	good visual material	go off main point	continuous talking
interest	enthusiasm	look bored	waffle
emphasise main points	examples and analogies	overload slides	too many slides
knowledge of subject	matched to audience	obscure audience vision	too much technical detail

Table 2.
Student group recommendations for effective presentations

viii) Report writing

Word-processed group reports are required from each of the projects. Guidelines and training support is provided with a video, examples of previous student reports and general and subject specific 'good practice' guidelines.

ix) Reflection - Personal Evidence Database (PED)

Students are also encouraged to reflect and record their experiences using an on-line Personal Evidence Database giving a selection of tools, information and sections tailored for students to complete 'overview notes' from workshops and an 'ongoing log' from projects to track progress and identify skills development.

Barriers

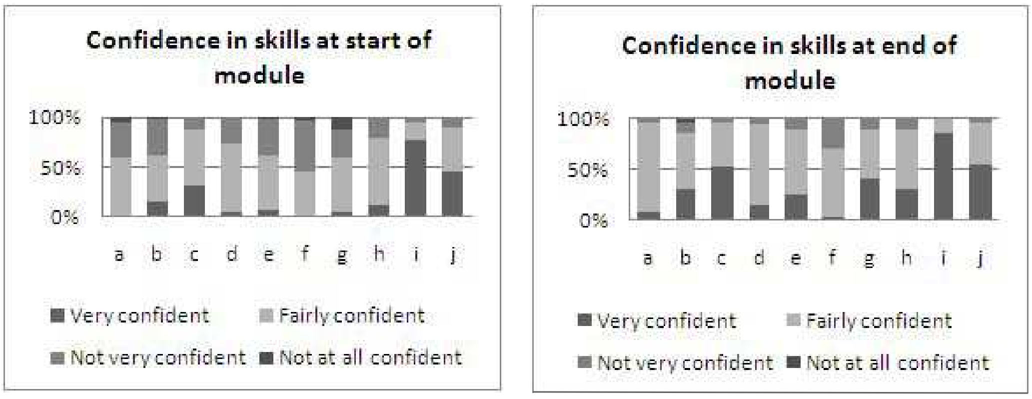
Project activities are widely identified as a valuable component of a mathematics degree programme but often restricted by concerns over implementation issues such as management, organisation and provision of project activities, training in skills, assessment, plagiarism, feedback, staffing, etc. Concerns seem intensified within group project activities, however the potential for enhancement of skills, peer learning and assessment are considerable together with greater efficiency on staff resources.

Enablers

Vocational Mathematics is unique within the mathematics programme at Nottingham as entirely group-project based and assessed through group project activities. Initially the module was introduced to provide students on the MMath degree ' Mathematics with Engineering' with the means to develop project-based skills prior to a substantial individual project. The widespread introduction of the MMath degree provided a major opportunity to revise the mathematics Programme. Support from the Head of School and modest financial support from the University to fund an external 'industrial consultant' to help frame the employability skills and assist with projects enabled the module to be initiated. The target cohort is now extended to final year BSc students moving directly to graduate careers or for MMath students improving their skills base ahead of a Fourth Year individual project. In addition, an extended version of this module is available to some MSc programmes prior to an extensive dissertation.

Evidence of success

At the start of the module a detailed skill survey based on student's intake perception of skills is conducted and this is repeated at the end of module. A sample summary of comparisons comparison for cohorts 2006-9 is shown in Figure 1.



a	writing a mathematical report;	**f**	interpreting open-ended problems;
b	making an oral presentation;	**g**	structuring a written report;
c	working as part of a team;	**h**	using appropriate mathematical terms;
d	expressing mathematical language;	**i**	using a word processor;
e	interpreting mathematical results;	**j**	making work look professional.

Figure 1
Comparison of student perception on their personal skills, categories a-j, from surveys taken at the start and the end of module.

Significant improvement is shown particularly from 'limited confidence' to 'very confident' categories but students also leave the module with more objectivity and perceptions are more aligned to realism.

General feedback is provided by student reflections from the PED such as:

> *"My enjoyment of this module ebbed and flowed throughout the time period. There were certain aspects that I did quite enjoy, such as the initial research into the problem and solving our model. But there were aspects that I didn't enjoy quite so much, such as the writing of the report. I also found the module to be quite stressful towards the end in particular, due to the importance of the final hand-in and consequently found it to be very hard work."*
>
> *"We had issues with members of the team's effort levels, this meant that when raising these issues with them I had to make it clear that I wasn't being personal or targeting them. I wanted them to work harder to make the final product better."*
>
> *"The presentation was confident and well structured. Our numerous practices and periodic alterations ensured a strong contribution from all members and a well paced, coherent report, clearly showing all our findings".*

Quality Assurance

Assessment within the module is based on written reports (80%) and oral reports (20%) for each of the projects; individual student marks are based according to both the group and individual achievements. Attention is given to transparency within the assessment process and consideration of peer assessment as covered in an early workshop. The reports are assessed independently by two module staff and according to detailed grade criteria in categories (8 for written and 5 for oral) using standard templates shared with students. A weighted group mark and detailed feedback is provided to each group project member. Individual student marks are assigned following peer assessment weightings based on unanimously agreed factors within a group or determined from confidential data returned to module staff.

Quality assurance materials are maintained alongside the provision of project materials to aid the assessment process and are made available to external evaluators:

- Oral presentations are recorded and digital files made available for feedback and detailed examination.
- Powerpoint presentations are required and electronic copies submitted for possible scrutiny.
- Written reports are required both in written and electronic (.pdf) format, enabling these to be searched by on-line plagiarism software and a report given to students.
- All subjective assessments are made by two independent module staff and collated on a spreadsheet that can be readily audited.
- An independent moderator is required to overview project assessments, review peer assessment and advise on final module marks.

Recommendations for others

The universal provision of substantial project activities remains an underdeveloped area of the undergraduate mathematics curriculum. Such activities have the potential of promoting individual study, research and employability skills in students and of highlighting the versatility of mathematics graduates. This is particularly relevant at a time when a number of external influences are indicating that degree specifications should embrace an extended range of subject specific and wider skills.

Implementation issues are covered by [13] and [14] which include a consensus of 'good practice' and possible templates. More recently two workshops supported by the MSOR-Network have brought together practitioners who are further pioneering the development of graduate and employability skills within a mathematical sciences programme [15, 16, 17].

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8.0 Summary, conclusions, recommendations and reflections

Summary, conclusions, recommendations and reflections

Summary, conclusions, recommendations and reflections

1 Introduction

1.1 Structure of the summary and conclusions

1.1.1 The summary that follows is structured in the same fashion as this publication as a whole, with sections covering each of the six chapters 2 to 7. In general specific references to the preceding articles are not made, but for further information about any of the topics covered here or more detailed arguments supporting our conclusions, please refer to the papers in the corresponding chapter. Where evidence is drawn from articles in other chapters, specific reference is made in the conclusions.

1.1.2 In places similar themes emerge from across the different chapters of this publication. We have, in general, allowed this repetition to remain in the summary that follows to illustrate how similar ideas have arisen in different circumstances.

1.1.3 In addition, in section 8 of these conclusions, we briefly discuss two issues which have recurred frequently throughout our work and which warrant some final remarks.

2 Access to mathematics degrees – how and why do they get here?

2.1 Choosing mathematics

2.1.1 The student body is diverse. Our students include those who are fascinated by the subject through to those with more ambivalence towards it. Staff need to recognise that the majority of students may not (yet!) share their passion for mathematics; conversely we need to take care that frustration with the less motivated students does not blind us to the reality that most students do arrive with a positive attitude towards the subject.

2.1.2 For the vast majority of students, the primary motivation in coming to university is to enhance their future career prospects. University staff recognise this but are not always comfortable with the resulting student attitudes towards the subject.

2.1.3 Students rarely have clear ideas at the start of their university career about their future employment, viewing mathematics as a degree which keeps open their options. Their future employment rarely involves high level mathematics, although generic mathematical skills are frequently in demand. *See section 7.3 for a fuller discussion and recommendations.*

2.2 Choosing a university

2.2.1 The reasons behind student choices about which university to study at are of course varied; the most cited primary reason is the reputation of the university or department. A substantial proportion of students choose their university for reasons entirely beyond the department's control. Only one in five students cites course-specific issues as their primary motivation for choice of university.

2.2.2 Students may judge 'reputation' largely according to UCAS tariff requirements, and as such might be independent of objective measures either of the quality of provision or the suitability for individual students. Departments with a high reputation get many applicants, and can therefore set a high tariff, which means their reputation amongst applicants is maintained.

2.2.3 League tables and the recently introduced National Student Survey (NSS) provide students with an additional way of judging departments. There is little correlation between current UCAS tariff and overall National Student Survey scores in maths departments, suggesting that departments with lower entry requirements are slightly more highly regarded by their current students. This development therefore has the *potential* to upset conventional wisdom about the 'best' departments in which to study, although this should not be overstated.

2.2.4 Universities and departments recognise the signficance of the NSS and are taking steps to minimise any negative impact. This has the potential to substantially improve provision in certain areas, whilst at the same time introducing the risk that a balanced educational decision-making process might be distorted by an obsession with improving NSS scores. Whilst this is an important development in the information available to potential students, it can only give a very partial picture of the provision.

2.2.5 Given the laudable diversity of mathematics provision in different departments, we consider it regrettable (if understandable) that a higher proportion of students do not consider the differences between courses more when making their application. Getting the right student on the right course for them has potential benefits for both staff and students, with increased satisfaction all round. We believe that more widespread consideration of course differences would be more useful than judging departments by league tables or UCAS tariff.

2.2.6 From our sample of students in one questionnaire, 87% said that, with the benefit of hindsight, they would still choose to study a mathematical course at university. 81% said that they would choose the same university. However, only 3 out of 5 said that they would choose the same course and the same university.

2.2.7 ***We recommend widespread promotion of our booklet '*****Maths at University'** ***to help students to consider the differences between courses and thus select the best course for them.***

2.3 Mathematical deserts and ecosystems

2.3.1 A significant minority of students wish to study from home and therefore have very limited choice of university. There is strong evidence that this is particularly true of students from ethnic minorities, those from lower socio-economic groups, and adult returners. There is some (weaker) evidence that students whose parents were not university educated are similarly less willing to travel in order to enter higher education. It follows that the lack of mathematics courses in some parts of the country will disproportionately affect students from these groups.

2.3.2 That said, we could find only weak evidence that lack of local provision was sufficient to deter many students. However we note the difficulty of identifying students who have chosen not to study mathematics.

2.3.3 ***We recommend that further work should be done, exploiting the cross-subject co-operation in the HE STEM Programme, in order to better understand the decisions taken by numerate students when choosing their subject and university.***

2.3.4 We acknowledge earlier work (see article 2.2) identifying that if mathematical deserts deter some students, this is likely to reduce the supply of mathematically qualified teachers locally. There is also evidence that absence of local university mathematics reduces the opportunity for outreach work in schools. Both factors represent a loss of mathematical opportunity for local school-children and hence are likely to reduce the number of students from these areas applying to do mathematics degrees, whether locally or further afield. We note that at present no single body has sufficient financial incentive to resource outreach work in these areas.

2.3.5 ***We recommend that universities closest to the maths deserts, the various mathematical societies and the higher education funding councils explore ways of funding outreach work specifically targetted at those areas of the country which lack a local mathematics department.***

2.3.6 We find that the economic pressures of a market-driven system will continue to leave some departments under risk of closure. Conversely, we can see no mechanism whereby increased demand for mathematics courses will result in universities without mathematics departments deciding to establish degree programmes. We therefore conclude that the problems of 'mathematical deserts' are likely to increase rather than improve, alongside a reduction in the desirable diversity of mathematical provision.

2.4 Adult returners

2.4.1 Mathematics courses have a much smaller proportion of mature students than the average for other disciplines, and indeed of other numerate disciplines.

2.4.2 Adult returners report some difficulties with undergraduate study. This may be because returners' courses are generally one year in length, and so they are still adjusting to studying, or because of not having techniques at their fingertips as standard entry students might, or because of lack of confidence.

2.4.3 Nevertheless, mature students often do very well. Some staff report that a nucleus of committed mature students can also have the wider benefit of encouraging an effective work ethic amongst the student cohort as a whole.

2.4.4 ***We support continuing efforts to increase the proportion of mature students studying mathematics at university in order to increase the number of mathematics graduates, widen participation to an under-represented group, and enrich the community of university mathematics.***

2.4.5 Adults choose to return to education for predictable reasons, most commonly in order to enable them to change careers, or enhance their current one, or return to work after raising families.

2.4.6 Those choosing to return to study mathematics often need to top up or revise their mathematical knowledge or general study skills before beginning an undergraduate course. There are five main options open to them: Open University courses, university year zeroes (preparatory or foundation years), Access to HE diplomas, A level and Polymaths. The pros and cons of each are reviewed in article 2.4 in this publication.

2.4.7 Potential returners find it difficult to obtain information on the pros and cons of various courses, and on possible career options in mathematics. For example, there is no centralised information available about university year zeroes, let alone on the full range of possible entry routes.

2.4.8 ***We recommend that a booklet outlining the advantages and disadvantages of different returners' routes be prepared, with the same information being available on the web, perhaps on the Adult Learners section of the Maths Careers website.***

2.4.9 ***We recommend the creation of a single search point for university year zeroes, equivalent to the Access to HE website. This should be closely linked to the Access to HE site, or part of a combined 'Adult Returners' site.***

2.4.10 The different entry routes have widely varying fee levels, with a complex array of potential sources of help to pay for the course. Although the information is available online, the rules are complex and the information distributed among a number of places. Students have difficulty estimating what financial support they can obtain, and don't always know about the full range of options.

2.4.11 ***We recommend the creation of a booklet, perhaps combined with that recommended in paragraph 2.4.8, giving a single guide through the financial labyrinth. The information should also be available online.***

2.4.12 We note that it is unclear what a potential adult returner does when they decide to return to university, especially given the lack of a single vocation associated with mathematics. What prompts a potential student to think of mathematics, and where do they look for information?

2.4.13 ***We recommend further work to establish the full range of information-gathering strategies which may be adopted by potential adult returners and the information they would find by pursuing these strategies.***

2.4.14 There is some anecdotal evidence of admissions tutors being reluctant to admit students from non A level routes. This may be because of unfamiliarity with the qualifications and assessment, and is compounded by the widely different amounts of mathematics in returners' courses. Deep concern has been expressed about the amount of mathematics in some access courses in particular.

2.4.15 The Polymaths course, currently running at only two universities, both in the north west of England, is validated by the Institute of Mathematics and its Applications. As such its mathematical content is high. There would be clear benefits to the mathematical ecosystem as a whole were this more widely available, but we understand that low numbers, low fees, and the fact that the benefits are spread across more beneficiaries than the host university mean that new courses have limited financial viability. There are various options, presented in article 2.3, for widening the availability of Polymaths.

2.4.16 ***We recommend changing the name of the Polymaths to one such as 'IMA Certificate of Mathematics'.***

2.4.17 ***We recommend the creation of a 'kite mark' for mathematical content for returners' courses, certifying that the course contains sufficient time and content to be broadly equivalent to A level. A possible mechanism for this could perhaps be an evolution of that current used for Polymaths.***

3 Student and staff experience of life at university

3.1 Overall student experience

3.1.1 The range of student experience is, inevitably, huge, reminding us that whatever we may say here or do in our courses, we cannot please all of the people all of the time. This further underlines support for a diverse range of courses and suitable means of getting the right students onto the right course. *See recommendation 2.2.7.*

3.1.2 Overall, students who said their confidence in mathematics and enjoyment of it had increased since coming to university outnumbered those who said that their confidence and enjoyment had gone down. However, a substantial minority (1 in 5) report enjoying mathematics less during their first year and even more report feeling less confident. This situation improves in later years, but significant numbers still enjoy maths less than they had done previously.

3.1.3 The presence of a substantial minority of students with less confidence and enjoyment affects (a) their likely engagement and understanding during their studies (b) the likelihood of their remaining within the mathematics community after graduation, and (c) their future NSS rating. All of these hinder efforts to persuade future potential students to study maths.

3.1.4 Students identified a range of factors which could either adversely or positively affect their experience of studying maths and university life overall. In general, these reflect the issues raised by staff in interviews, and in the assorted literature from maths educators, suggesting that (a) staff are well aware of what the issues are, and (b) that we still need to continue to address these.

3.1.5 *See also paragraph 2.2.6.*

3.2 Personal and social issues

3.2.1 For many students, arriving at university represents the first time that they have lived away from their parents. Many are in an unfamiliar city and have few old friends around. As such, mathematical and study skills are only a part of the challenges that they face.

3.2.2 There is evidence that students who successfully form strong social networks quickly are both happy, and successful in their studies. Staff can aid this process both during induction and throughout the course, for example through social activities, group work projects, or effective use of an online forum.

3.2.3 One step removed from the students' immediate network of peers, there is evidence of students seeking a 'community of learning' within their departments, with encouragement for peer-assisted learning programmes, social events, and more appreciation of the departmental research work.

3.2.4 *For a fuller discussion of these issues, and recommendations, see also section 4.*

3.3 General educational issues

3.3.1 Students generally view contact with staff – formally timetabled or informally – as vital to their positive experience. We would be surprised if staff did not agree, yet of course all the financial pressures militate against increasing our contact with them.

3.3.2 The switch from small A level classes to large lectures is challenging for most students. Some find this surprising. The need for more independence is relished by some and difficult for others. Students rate the assorted styles of small group teaching and informal help from staff far more favourably than lectures, which are often seen as too impersonal and occasionally viewed with disdain. Small tutorial groups are highly regarded where these are available.

3.3.3 Where students feel they have found effective support – whether from staff or from fellow students – they are generally positive about their experiences. However, not all students appear to find their own community of learning within their universities. Staff can and do try to encourage formation of student support networks, and access to staff help, in a variety of ways which are reported more fully in Chapter 4.

3.3.4 In line with findings from the NSS, feedback and assessment were the issues raised most frequently by students when we asked them to identify possible improvements to their course. Issues included the frequency and number of assessment, and the value of the feedback received.

3.3.5 Some staff identify a lack of motivation, and willingness to work hard in some students. Whilst we recognise this in our own students, we also raise the question of whether we have unrealistic expectations of our students, perhaps comparing them unfavourably to our own atypical experience of mathematics and university life.

3.3.6 Many staff report students being too focussed on getting through the next test, rather than gaining an understanding of the subject. The amount of testing in schools and pressure on teachers caused by league tables are seen by some as responsible, suggesting that government priorities with school testing may be undermining rather than improving students' education.

3.3.7 ***We support the abolition of testing at Key Stage 3 and recommend further reduction in government-driven school testing and consequent league tables.***

3.3.8 *For a fuller discussion of these issues, and further recommendations, see also sections 4 and 5.*

3.4 Mathematical issues

3.4.1 One aspect of the diversity of student experience is apparent in what they say about the level of difficulty associated with undergraduate mathematics. By 'difficulty' we might include the overall workload, as well as the intellectual challenge associated with getting to grips with the subject matter. Some relish the challenge; some feel lost and at sea. The question for staff is always: are we pitching our courses at the right level? Is our subject's reputation for being hard something we should protect and maintain, or is it, as one student said, *too* hard?

3.4.2 Students talk about the increasing difficulty of the work across all levels, not just the difference between school and university. We note that it would be odd if things didn't get harder as students progressed, but also note that a perception of difficulty may be a reflection of the work itself, but may also be a reflection of how well the student is coping with other aspects of university life.

3.4.3 Inevitably, some students do less well than others. Unfavourable comparisons with peers can be disheartening. A particular problem may be apparent on courses where the entrance requirements are high, where students who were high-flyers at school become struggling students at university. From the perspective of wanting to increase the number of mathematical graduates, these students present a particular challenge to academic staff. They are more mathematically able than most people, motivated to do maths; and people who should be happy successful mathematicians, and yet by going to a university with even more able students, their overall experience can be a very unhappy one.

3.4.4 It is notable however that what students say about adjusting to mathematics at university is not limited to, or even focussed on, the idea of a gap between school and university curriculum *content*. Indeed, their discussion of the merits or otherwise of A level revision at university suggests that they do not perceive a gap in these terms. Rather, students talk about the nature of mathematics and our approach to it (for example, in notation, approach to rigour, and abstraction). Staff discuss similar issues but students report little time or effort devoted to developing these skills and attitudes. If we view these as important, is this reflected in how we teach? For a discussion of two approaches to this, see articles 7.5 and 7.7.

3.4.5 ***We recommend that curriculum designers and module tutors consider the best means of allowing students to develop these skills, having realistic and full recognition of the students' existing abilities on arrival.***

3.4.6 Whilst acknowledging the inclusion of some very good students, staff identify other shortcomings in some students' mathematical abilities on arrival, covering their competency with mathematical techniques, written communication of mathematics, knowledge, mathematical attitudes and understanding. In addition some staff regret a lack of passion for the subject from some students. Many staff feel that student abilities have declined over recent years.

3.4.7 We reflect that describing these as 'shortcomings' may be unfair on the students, who have successfully leapt the hurdles before them and gained a place at university. Perhaps we need to adjust our expectations to reflect the reality, rather than wishing that the world were different from what it is.

3.4.8 *For a fuller discussion of these issues, and recommendations, see also section 7.*

3.5 Relationships between staff and students

3.5.1 We find evidence that students perform well when they feel valued and part of a wider learning community; as such a full and frank educational relationship between students and staff, in which the students are treated as partners in their own education, creates a perception that we value them as well as encouraging them to develop a more mature and reflective attitude towards their work.

3.5.2 We recognise that, particularly in the early stages of their university career, students can be no more than *junior* partners in this experience, and that developing the maturity expected of them may take some time. A gradual reduction in the level of support, and a gradual increase in the expectations we place on them, is appropriate. However, at all stages, students benefit from being fully informed about why and how we make the decisions which affect their lives and education.

3.5.3 We note that staff perceptions of student 'shortcomings' discussed in paragraphs 3.4.6 and 3.4.7 risk damaging the relationship with students leading them to feel insecure, unconfident and disillusioned with the faculty.

3.6 Final thoughts about transition

3.6.1 Transition to university life will always present challenges for all students and major hurdles for some, and accordingly it is something which staff interviewed during this study, and the wider mathematical community, have grappled with for some time. As discussed above, the issues students face include problems moving away from home for the first time, new approaches to teaching and learning, surprise at the style of university mathematics, and difficulties coping with more advanced work.

3.6.2 We note that these problems continue for some beyond their first arrival at university. For example, many students leave university halls at the end of their first year and for the first time live truly independently. If additional staff contact time is supplied in the first year, its withdrawal later can leave students feeling unsupported. Higher levels of study introduce more advanced work, presenting some students with difficulties. Hence, whilst transition to the first year at university is probably the most severe change, staff need to be aware that treating these as problems which can be eradicated in the first year is risky.

3.6.3 We have severe reservations about the use of the term 'bridging the gap' to describe mathematical work in the first year aiming to raise students' skill level to some particular level deemed appropriate before 'real' mathematics can begin. Our students arrive with one set of skills and knowledge, and we aim to have them leave with a different set of knowledge; our job is to facilitate that development throughout their time with us. Talking about 'bridging a gap' is a reflection of an arbitrary decision about the appropriate starting point, irrespective of the reality of the student intake. Rather we would prefer to see the gap eliminated (as the departments in this study have largely tried to do) by realistic adjustments throughout the curriculum.

3.6.4 *For a further discussion of curriculum issues, and recommendations, see also section 7.*

4 Student Support

4.1 Friends

4.1.1 Students see friends as the single most important component of a support network - it is easier to ask a friend, and the ensuing explanation may be more at the student's own level. The role of the university in this is to create conditions conducive to the forming of friendships, and hence mutual support networks.

4.1.2 This can start at induction, with events designed to build up a community. During the year it can be encouraged by group working - perhaps as described in paragraph 4.3.1 below with the aid of mentors, or in staff led tutorial groups. Convenient and convivial working places are also helpful in forming a community particularly if, as described in paragraph 4.4.1 below, they are associated with a drop-in support centre. Mature students can often be helpful in establishing support networks and in identifying students that are isolated.

4.1.3 ***We acknowledge and support the diverse initiatives, including support centres with convenient work areas, peer mentoring and social networking sites to foster the growth of mathematical communities, recognising that this provides a key mechanism by which students gain help and a sense of belonging. We recommend that staff work to encourage a culture of a shared mathematical community of learning incorporating students from all levels, academic and support staff.***

4.2 Personal contact with staff

4.2.1 Ways for students to meet individually with members of staff vary between institutions. Some operate an open door policy and others have office hours while some institutions also operate personal tutor systems. Students may find it difficult to knock on an office door, but can find it helpful to have a member of staff that they relate to specifically and this sometimes helps in sorting out problems with other modules. Personal tutors can be used to run group projects, but tend to be under-used when the system is one of occasional appointments with tutees.

4.2.2 *See also section 3.3.*

4.3 Peer Mentoring Schemes

4.3.1 First year students welcome the opportunity to be able to talk to students from later years about both academic matters and life at university on a more equal footing than they might feel (initially at least) with members of staff. Peer mentoring schemes also provide an opportunity to meet other first years and hence help to establish a peer support network, and also to gain confidence in interacting in discussions about mathematics and learning to work in a team. This has a consequent effect in helping students to make more of staffed tutorials and generally in fostering a learning community.

4.3.2 Two rather different mentoring schemes are described in articles 4.2 and 4.3, with final years mentoring a first year group of 6 - 8 students centred around a specific project (article 4.2) and mentors from later years taking a rather more general session discussing both academic and non-academic matters with groups of up to 15 students (article 4.3). In both schemes it was emphasised that the mentors' job is to facilitate discussion and not to teach.

4.3.3 Mentors gain in confidence and develop skills in leadership, teamwork and interpersonal communication, through both the training provided for the role and in actually performing it. Students recognise that these skills are useful for employment and can be included in their CV. This recognition is testified to by the fact that in neither scheme was there any difficulty in recruiting mentors despite the voluntary nature of the role. An additional benefit is that mentors feel that they end up with a better understanding of some of the first year material having helped first year students to understand it.

4.3.4 In aiding the development of a learning community the mentoring process helps to increase student satisfaction and hence can aid retention. It can also provide useful information on how the first year modules are proceeding and practical help with first year group project work.

4.4 Drop-in Centres

4.4.1 Drop-in sessions are now run by many universities. Students may be more likely to come to a drop-in session than to a member of staff's office because the drop-in session is neutral ground, and staff members are timetabled to be there so that students don't feel that they are interrupting them. Students can find that an explanation from a different person can give the different angle they need to sort out a problem, and that they can also obtain advice and additional resources. Where there is a space within the maths dept dedicated to support then students tend to naturally congregate there which aids the development of group learning strategies and of a mathematical community.

4.4.2 The quality of the student experience is enhanced which in turn can improve retention and progression. Working in a drop-in can aid understanding of the sorts of problems students have with the lecture material and also of their diverse backgrounds.

4.4.3 Probably the longest running drop-in centre is the Maths Support Centre in Loughborough and the development and operation of this centre is described in article 4.4. During the time that this centre has been up and running, a large number of supporting resources have been developed and the article also describes how many of these may be accessed.

4.4.4 ***We acknowledge the value of drop-in support centres and recommend the prescription given in article 4.4 to set one up in places where they do not currently exist.***

4.5 On-Line support

4.5.1 A variety of on-line support methods exist, from Facebook and other social networking sites, through commercial VLEs such as Blackboard and Moodle providing information and discussion forums, to bespoke software giving additional interactive possibilities. Email also plays a vital role in helping to provide a prompt and efficient way to answer student queries.

4.5.2 The use of Facebook is now so widespread by students that it cannot be ignored as a means of helping to propagate a mathematical community. At its best it allows interaction between year groups and informal mentoring and can act as a catalyst for actual meetings (eg in the formation of a mathematical society). There are dangers which need to be guarded against however, including out of date information abut the course being passed from later years back to first years, and the setting up of rival Facebook groups. A description is given in article 4.5 of experiences in using Facebook at Coventry University.

4.5.3 A system for students to keep an on-line progress file is described in article 4.6. Students make weekly entries reflecting on their progress in all their modules and there is a small amount of credit attached. They can be initially reluctant but, when through explanation and personal experience the part that such a file plays in their study becomes apparent, their engagement with it usually improves. Its advantages are seen as allowing students to reflect on their learning, to manage their time better, to develop skills in self-appraisal, to take control of their learning and hence to develop strategies to deal with problem areas. An additional feature is the capacity for staff to read and respond to comments in the files, gaining useful rapid information about how a module is going and, where necessary, giving rapid feedback and advice to individual students.

4.5.4 ***We recommend consideration of an on-line interactive system for student reflection both to help students become autonomous learners and as a vehicle for rapid support.***

5 Teaching and engagement

5.1 General

5.1.1 We found strong evidence of staff being committed to and thoughtful about their teaching responsibilities.

5.1.2 Nevertheless we recognise that both limited resources, and the fact that future academic career opportunities depend primarily on research records can limit the scope for developing teaching, including new and innovative methods where appropriate. Where support for developing teaching exists it is often in the form of short-term fellowships rather than ongoing support.

5.1.3 ***We recommend that departments and universities should further support and recognise staff efforts to improve teaching provision, and develop career paths with parity of esteem between teaching and research.***

5.2 Lectures, notes and engagement

5.2.1 In lectures, students say it helps them to come to grips with theory if illustrative examples are given. They particularly value live examples, seeing someone *do* live mathematics in front of them, at a pace which they can match. It is easier to do more of this if the lecturer is not tied by the constraints of an over-full syllabus.

5.2.2 Good quality online notes are valued by students as a pragmatic back-up to lectures, but for students to get the best from the provision, it is useful to have an explicit rationale for why notes are provided, and to explain that rationale to the students. Part of this explanation should be about how the provision of notes relates to lectures, and the place of each in their overall learning experience.

5.2.3 Attendance is important but more so is *engagement*. Monitoring attendance is commonplace, but there is now some growing experience of monitoring engagement with the support of web technology.

5.2.4 The role of technology continues to develop, with case studies in this section on web-based learning and on the use of tablet PCs and screencasts.

5.2.5 *For further discussion of student views of lectures, see also section 3.3.*

5.3 Small group teaching

5.3.1 The variety of arrangements for small group teaching across institutions is much wider than in our approach to lectures, from small tutorial groups of six students through to much larger exercise classes.

5.3.2 Students are generally appreciative of small-group teaching.

5.3.3 General cross-module classes, provided in addition to module-specific classes, may provide an opportunity for seeing the links between different modules and developing skills which are generic to mathematics rather than specific topics.

5.3.4 Surgeries can provide a forum for discipline-specific support, are popular with students, and may be used more than drop-in sessions which are open to other disciplines.

5.3.5 Small group classes directly after lectures enable students to rehearse the lecture material immediately but may reduce effective use of staff time and encourage student disengagement. Holding exercise classes at a different time during the week allows staff to establish an expectation that students will arrive prepared and can result in a better use of staff time.

5.3.6 Students generally see their exercise classes and tutorials as being more useful than lectures. This raises the question about whether the current ratio of lecture to tutorial is appropriate.

5.3.7 ***We recommend that staff review the balance of different styles of staff-student contact time and consider whether the current practice is the best possible, or a product of historical habits.***

5.3.8 Very small groups can provide multiple opportunities which are generally appreciated by both students and staff. Staff may wish to consider whether resources can be found to enable such groups more widely.

5.3.9 Blurring the boundary between lectures and small group styles of teaching has some educational advantages but may be difficult with larger cohorts. Certainly students want some smaller groups where they feel able to ask questions, so even with large cohorts some small group teaching is required. But a longer, less transmissive, more varied style of "lectorial" and consequently larger exercise classes or tutorials may be beneficial in some cases.

5.3.10 *For further discussion of student views of small-group teaching, see also section 3.3.*

6 Assessment

6.1 Coursework

6.1.1 Marks are an important motivator. For coursework of a routine nature there is a balance to be struck between awarding sufficient marks to motivate but not so many that guarding against copying becomes a burden. For longer, more open ended coursework the verification of originality is less of a problem and coursework may then become the major assessment vehicle for a module. The most effective assessment pattern may be one that combines several types of coursework with examinations.

6.1.2 Frequent short coursework for first year students with rapid feedback plays a key formative role for students and enables staff (especially when combined with attendance tracking) to effectively monitor the progress of individuals. This is particularly true where academic tutors mark work from their own tutorial group. For large groups rapid feedback requires careful organisation with a team of markers. There is a small dividing line between providing too much and too little challenge in the tasks given and structured example sheets moving from worked examples to tutorial questions to related assignment questions may be useful.

6.1.3 Longer coursework assignments allow the chance to undertake more realistic problems requiring original thought while exhibiting competence in the use of core techniques and technology. They should however have a clear starting point in lecture material.

6.2 Assessment Schemes

6.2.1 The UK needs some excellent mathematicians and one priority of an assessment scheme is that it identifies and validates these - including those who develop late. At the same time committed mathematicians who are not researchers, but who have excellent skills for employment also need to be identified. For students who find greater difficulties, a scheme needs to provide chances to recover failure and poor marks without compromising standards. If students are genuinely likely to fail they need to be informed early so that they can switch to a path which is more appropriate for them.

6.2.2 The first time a student is assessed is likely to be in a diagnostic way to evaluate their competence with fundamental techniques and hence arrange appropriate support - this may be done repeatedly through the first year (see article 7.6 for example). Another important stage is at the end of the first year. Bearing in mind that students report finding the transition to the second year can be as difficult as that between school and university, and also that students can pass knowing only 40% of the material, care is needed to design first year assessment so that students passing through to the second year are properly prepared. Where courses are semesterised then timing of exams can be an issue, with the prevalent view amongst staff being that it is better to have all exams in a year together to aid student perception of course coherence.

6.2.3 Schemes vary substantially both in the total credit needed for a degree (280 to 340 points in courses looked at) and the balance between years. To reward both consistency through the years and exit acceleration it may be appropriate for a scheme to have two alternative ways of calculating marks - one which relies only on the final year and one which takes into account a proportion of previous years marks. The final mark would then be whichever is the greater by the two methods of calculation. Potential high fliers may exhibit rather different skills in different courses. There is more than one way to achieve a high standard and the comparison between institutions may be effectively that of comparing how well the best students are identified and motivated.

6.2.4 Flexibility to cope with failure is achieved in different ways in different institutions. Some institutions allow a student to obtain a degree while having failed three or four modules as long as the overall average is sufficiently high. Other institutions are stricter about the total number of credits required, but allow students to carry some failed modules into subsequent years. When extenuating circumstances are accepted for coursework there is again a variation in approach. Some institutions require students to still complete the work that is affected by the circumstances while others do not - substituting instead an average mark computed from other work the student has completed. With frequent short coursework tasks some flexibility can be achieved by including a couple of spares so that students can obtain full marks on perhaps 8 out of 10 assignments.

6.3 On-line computer generated assessment

6.3.1 On-line coursework is useful for automating the marking process and providing instant feedback. There is also often the advantage that questions can be randomised so that the problem of copying does not arise. Article 6.3 is a case study which describes the long term experience gained at Birmingham using software to produce random questions in calculus and algebra with worked solutions. While recognising that such a system will only work effectively for particular areas of mathematics, it has been found an invaluable tool in coping with increasing numbers of students. The case study describes the stages of evolution of the system and the considerations required in setting suitable questions for which worked solutions can be automatically provided.

6.3.2 ***We support the further development of on-line assessment where appropriate, acknowledge the depth of experience embodied in the Birmingham project and recommend this as a good reference point for institutions wishing to become more involved with this type of assessment.***

7 Curriculum content and course design

7.1 Diversity in mathematical sciences

7.1.1 We perceive that students are diverse and so are their aspirations, interests and drivers; mathematics is a diverse discipline and so are the demands made upon it.

7.1.2 ***We therefore fully support the tenor of the MSOR Subject Benchmark statement wherein it is acknowledged that mathematical degrees are diverse, ranging from highly theoretical to highly practical, and that this is healthy for the discipline.***

7.2 What constitutes a mathematical graduate?

7.2.1 We perceive that there is a widespread view in the mathematics community that the key qualities of a mathematician are expressed largely through a set of skills, attitudes, ways of thinking and behaviour, rather than knowledge of any specific mathematical topics or content, although the qualities are of course based in and developed through some body of content and knowledge.

7.2.2 In contrast we perceive that there is a tendency for curriculum designers and developers in mathematics to focus on content more than overarching mathematical skills and qualities. This is understandable given that mathematics is in part hierarchical and curriculum must be coherently constructed. It is, though, also potentially harmful, in that it can lead to overcrowded curricula, which tend to obscure the important common features of the discipline, and obstruct and damage a student's ability to engage fully with the mathematical way of thinking.

7.2.3 ***We suggest that course designers be prepared to think radically when reviewing amount of content, and that they consider significant reductions in the number of specific topics covered, with the time freed being used to work explicitly on the development of the skills and qualities and ways of thinking of a mathematician, rather than expecting these latter to develop incidentally***.

7.3 Employability and careers awareness

7.3.1 For the vast majority of students, a primary motivation in coming to university is to enhance their future career prospects. The statement "I need a degree to get a good job" was rated very or quite important in their decision by 93% of students. For university staff with different priorities this can easily be forgotten.

7.3.2 Very few students start with the intention of doing a job which we would describe as heavily mathematical and few use advanced mathematical ideas in their future work. They do however often do jobs which require the key mathematical qualities and attitudes such as logical thinking, or lower level mathematical skills (e.g. in teaching to A Level standard), or general quantitative skills such as effective use of spreadsheets for various tasks. They will often be in competition with students from other disciplines, in terms of their generic skills and qualities such as communication and team working skills.

7.3.3 If academic staff explicitly recognise the breadth of student aspirations, and take the opportunity to help students to understand what doors may be opened by their mathematical course and to achieve their aims, then students are generally more likely to graduate broadly satisfied, and consequent positive feedback loops will help to maintain the health of the mathematical ecosystem.

7.3.4 We therefore recommend that curriculum designers consider explicitly the development of key qualities, skills, attitudes and behaviours required of a mathematics graduate to match content and educational activities better to both student aspirations and actual destinations.

7.3.5 In particular we support a continued and in some cases growing focus on the role of key graduate "employability" skills within mathematical courses, such as communication and team working skills, with support for and sharing of innovative ways of embedding the development of these within a mathematical framework.

7.3.6 Whilst students are primarily concerned with their future employability, relatively few of them have any clear detailed idea of their future plans. In many cases the decision is significantly influenced by a belief that a mathematics degree opens a wide range of career doors, and is therefore a good degree for those who want to keep their options open.

7.3.7 Despite a belief that doing maths opens many doors, students' knowledge of what careers they might follow appears to be somewhat limited, with traditional destinations of finance related jobs and teaching being most widely cited.

7.3.8 We support the work of the Maths Careers website and continued outreach work in schools to improve knowledge of career options.

7.3.9 ***We recommend course designers consider appropriate ways to include careers awareness work within their mathematical courses, and support dissemination of innovative ways of sharing practice in this respect***.

7.4 Foundation degrees

7.4.1 We have discussed issues surrounding the current and possible future involvement of the HE mathematical sciences community in the employer engagement agenda as it involves Foundation degrees.

7.4.2 While we perceive no demand for a Foundation degree in Mathematics alone, we consider that there may be opportunities for involvement not only through providing "service" mathematics to more vocational subjects, but also through *FdSc Mathematics with X* or *FdSc X with Mathematics*.

7.4.3 Crucial issues identified include assessing or stimulating demand, viable modes (part-time distance learning, full time), entry requirements and employer constituency. Given uncertainties about viability, we raise the possibility of a national part-time distance learning programme.

7.4.4 We recommend that work on identifying demand for a mathematical Foundation Degree, and on consequent course design, be continued as part of the national STEM project as outlined in Article 7.4 in this publication.

8 Reflections

In the preceding section, we have summarised our findings over the range of access to university, student and staff experience, student support, teaching, assessment, curriculum content and course design. Inevitably, many aspects of what we have found span different subjects (and so alternative categorisation would have been possible). As we come to the end of our work, it feels appropriate to conclude by reflecting on a few emerging themes which have struck us most forcefully.

Let us start by stating the obvious: our students are people first, with all the variation that that entails. Indeed our student body is diverse in age, ability, social group, ethnicity and previous experience reflecting most facets of society, in kind, although not in proportion, despite widening participation initiatives. Consequences of this are that students come into study with a correspondingly wide variety of aspirations and attributes.

Of vital importance though research mathematicians are, very few students enter university with either the desire or the capability of becoming one. Most students are motivated by a desire to "get a good job" and see mathematics as a passport to this. Although not future researchers, many go on to be good practical mathematicians, excellent teachers, or to make valuable contributions in roles which are not mathematical. A healthy mathematical ecosystem needs all of these groups.

Students wanting to study maths represent a broad spectrum of intellectual ability, mathematical knowledge and life skills. As well as variation in ability, students vary in their capacity to make the most of their course. Some, usually including mature students, are highly focussed and self-disciplined. Others require a lot of support to establish an effective study pattern.

The implications of this diversity are that maths undergraduate education must take students from a wide range of starting points to a wide range of finishing points, and therefore inevitably via a wide range of routes. For many students the ability to think and communicate clearly, to cooperate with members of a group and see the place their job has in the context of the employing organisation will be more important to them as future employees than any specific mathematical content. For some the mathematics they have studied will have little relevance. Others will need to have highly specialised mathematical knowledge. It would be surprising if any one course could successfully match the diversity of students coming into university to this variety of required skills. A natural consequence is that course designers make different decisions about their courses in order to best serve the sub-spectrum of students and student aspirations they encounter at a particular institution. Each maths degree occupies its evolutionary niche. For example, some are highly theoretical while others are more practically and technically based. Although increasingly in demand from employers and generally seen as a good thing, non-mathematical material such as career awareness and employability skills occupy a varying proportion of degree programmes.

In designing a curriculum we need to recognise that we are designing it mainly for people who have different aspirations to ourselves - people who are not going to end up as professional mathematicians. Too much emphasis on including the maximum amount of content is likely to be counter-productive, since in the headlong rush to the end of the syllabus there can be insufficient time for reflection. Mathematics graduates are generally valued for their logical thinking and problem-solving ability rather than knowledge of specific content, and this needs space to develop.

Despite having argued that, for good reasons, different maths degrees can fulfil rather different needs, it is important not to close doors. People develop in unpredictable ways and, for instance, some may realise part way though the course that they have the confidence, ability and motivation to become researchers. Any course should be capable of recognising and validating this talent - albeit in different ways - and hence be able to steer the student towards appropriate postgraduate education.

This existing range of degrees is not widely recognised among applicants and in order for students to join degree courses to which they are best suited it is desirable that more information is made available. For school leavers this need is being addressed by the "Maths at University" booklet described in article 2.5. For adult returners there is a need to bring information together and particularly to include advice on the pros and cons of various returners' routes into HE.

A further aspect of our students' being human is that, for the most part, they are social creatures. We see a great benefit for both students and staff in our fostering a mathematical community within a university. From a student's perspective, this needs to include their peers, students from other levels of study, and academic and support staff.

The practical benefits of this are many and varied. Students with a strong network of peers have a ready source of both personal and academic support, and often form the nucleus of their social networks outside academic work making them happier overall. Connections with students from higher levels of study widen and enrich their mathematical experience, and provide reassurance about their ability to manage the work. For higher level students, connections to newer students provide opportunities for them to revise their earlier work, and to gain experience of explaining mathematics. A good relationship between students and staff enables students to feel at ease asking questions and discussing problems. However, students need to adjust during their university life to less staff input than they had at school, both for the obvious reason that we have high student:staff ratios, but also because they should be developing into more independent people. Effective student networks for their social, support and academic needs have the additional advantage that it reduces their demand on staff time.

With this in mind, we see that much effort to ease the 'transition' to university study should focus particularly on helping a student to develop the social and support networks amongst each other and develop a good working relationship with staff.

Beyond the practical benefits of an effective learning community, there are less tangible but arguably more important advantages of students having a strong sense of belonging. Students who feel part of a wider community, and who feel valued by their peers and staff, are generally happier students, and as such are more likely to enjoy their studies, work hard, succeed in their studies, and leave with a positive memory of their time as university mathematicians. With a more cynical eye on outside measures like the National Student Survey, they are also more likely to rate us highly and forgive us our trespasses.

Staff, of course, have a large number of students and a limited amount of time; there is a risk that these translate into our seeing our students as numbers or as a drain on our time. We believe that all staff need to guard against this and propose that an approach of building a full and frank educational relationship with them is an extremely positive means of ensuring that they are, and feel, valued. When students understand why we have limited time, they respect this and develop other means of working; when they understand why the assessment rules exist, they feel less resentful about complying; when they know why we teach what we do, they see a purpose to it and engage more fully; when their views are genuinely *part* of the decision-making process in which they are involved, they are more forgiving if other considerations mean we reject their ideas.

We were particularly struck by a quote from one student who was very positive about their university experience.

> *"I feel that the tutors and students work as a team aiming for one goal and that is the students' understanding and enjoyment of the subject".*

That sense of common purpose between students and staff is surely a positive thing? We fight shy of saying that we should treat students as 'equals'; their developmental stage, both personally (especially for school-leavers) and academically (for all students), means that a more appropriate phrase might be 'junior partners' in their own education, albeit becoming more senior as they progress through the course. Alongside making them feel valued and part of the process, this attitude towards students creates an expectation that we expect them to behave as partners too. Whilst some will take longer than others to develop these skills, it is an expectation that most students live up to eventually.

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