
Chapter 13: Progression within mathematics degree programmes

Tony Croft & Michael Grove

Abstract

Several independent research projects report that the enjoyment of mathematics by many undergraduate mathematicians decreases as they progress through their degree programme and this decrease is accompanied by increasing disillusionment and disengagement with their course and alienation from mathematics itself. These are students who *choose* to study mathematics at university and who are relatively well-qualified. Moreover, it is often the case that students who report such feelings are not failing students – indeed many are doing rather well. Of course, many other students find their undergraduate experience of mathematics to be extremely rewarding but the prevalence of studies reporting disaffection suggests that this is an issue worthy of exploration within a book on transitional issues affecting undergraduate mathematicians.

This chapter will review the evidence for this phenomenon and unpick the reasons students give for their changes in attitude to mathematics. After establishing the context for the chapter we present a brief review of the literature in this field. The evidence suggests that this state of affairs can be attributed, at least in part, to the mismatch between students' hopes, expectations and aspirations and the reality of learning mathematics at university level. Sometimes, traditional pedagogies and practices can exacerbate this situation. We will go on to provide several examples of ways in which some lecturers and departments have attempted to modify practices in order to improve the student experience of university mathematics. We summarise the findings of selective activities and projects that provide pointers in the hope that they might inspire or provoke a discussion amongst individual lecturers and more widely within departments about ways in which disillusionment, disengagement and alienation might be ameliorated so that the experience of undergraduate mathematics is truly rewarding for all who choose to study it.

Introduction and context

The ‘sophomore slump’ is a well-documented phenomenon whereby students in the second year of their university studies can feel the ‘second-year blues’. It has been the focus of a number of studies, although these have not specifically dealt with second year mathematics undergraduates. A recent, substantial contribution to the literature is that of Thompson et al. (2013) which is described as a first attempt in UK higher education to investigate the second year experience and issues associated with it. Of course students in their first year of study can be unhappy too. During the first year some fail to adjust to university life, both socially and academically. They perhaps struggle with the depth and breadth of the mathematical material that is expected of them, or fail to adapt to new approaches to learning. They might experience challenges living away from home for the first time or establishing new friendship groups. Such long-standing challenges at the school/university transition are not only well understood, but have received considerable attention: academically, through diagnostic testing (see for example MathsTeam, undated), first-year curriculum change (Savage & Hawkes, 2000:3), provision of additional support (see Chapter 4 in this book); and socially, through university experience days, buddying schemes, students union activities, halls of residence activities and so on. Moving into year 2, any initial ‘novelty’ and enthusiasm felt for university life has perhaps long-since waned; there is a realisation that the work is getting harder and requires an increasing proportion of a student’s time coupled with the expectation that students are more independent and mature learners. The stakes are also starting to get higher; in the majority of universities performance in the second year contributes towards final degree classification. Thompson et al. (2013) discuss the wide range of factors which contribute to disengagement and underperformance and argue that *“the second year is a pivotal stage in the student life cycle and that academic and support staff need to be sensitive to the complex range of issues students may face in their second year”*.

Whilst students from any discipline may experience this sophomore slump, for many mathematics undergraduates the problems can be severe and can persist through the remainder of their degree programme to the extent that they describe negative feelings about their mathematics degrees even after graduation (Goulding, Hatch & Rodd, 2003). We argue that there are reasons why mathematics students might be particularly affected:

- a) Some question the purpose of studying abstract concepts of which they have little understanding, and see little in the way of application of much of the mathematics they are learning; many come to realise, quite rightly, that they will never use many of these specific mathematical techniques again.

One might argue that this is true of many academic disciplines studied at university; however the evidence from a study we cite later suggests that an important reason for students choosing to study mathematics is because they believe the mathematics they will learn will be useful and that they will use it to solve real world problems and yet many find that this is not necessarily the case.

- b) As we cite below, students report feelings of alienation, they describe narratives of existing on the margins and not feeling part of a learning community.

We shall point to research which suggests that the ways in which mathematics teaching is traditionally 'delivered' to students can exacerbate such feelings for some, though not all.

- c) Less academic support may be available in year 2 during a period in which the mathematics may, depending upon the type of institution in which it is being studied, become increasingly formal and abstract. Whilst a reduction in support may be a feature of the second year for students of any discipline, mathematicians in particular may no longer have access to mathematics support centres (established principally for first year students) which they may have relied upon (sometimes heavily) during their first year. Students report that there is less in the way of traditional tutorial provision. Frequently, closed-book final examinations are the predominant mode of assessment.

We would like to emphasise that such negative feelings, whilst commonly reported, are not ubiquitous, and for many students, university mathematics continues to provide challenge, inspiration and a continuing love of the discipline. For these students the curriculum and the traditions and practices of university mathematics departments are not alien and the students thrive. The focus of this chapter though is not upon the students who are enjoying their courses and thriving mathematically – they will continue to do well. Rather, in the spirit of encouraging a more inclusive mathematical experience, we focus here on those who are not. Evidence that there are a sufficient number of such students to merit consideration of this issue at all can be found in studies such as that by Brown, Macrae, Rodd and Wiliam (2005) described in more detail below, which found that in a survey of undergraduate mathematicians (N=150) in two English universities, over 20% failed two or more modules (out of six) in their first semester examinations in year 2.

Literature review

In an effort to understand better the nature of the challenges at second year level we have reviewed a range of relevant research studies. From these we have extracted five themes which are common across many and which we discuss further. Of course, some of these themes will have resonance in disciplines other than mathematics, but where there are mathematics specific issues we draw attention to these:

1. The importance of a sense of belonging and inclusion in a peer or departmental community and the learning and teaching relationship between staff and students; alienated students refer to lecturers' lack of interest in them.
2. The quality of teaching – often cited by students as a reason why they disengage; poor teaching means that advanced topics are made even harder to assimilate.
3. The nature of university mathematics and the pedagogic practices of departments and of individual staff members which can often fail to align with the preferred learning styles of students.
4. Many students are encouraged or choose to study mathematics because they were 'good at it' when at school. This may change when they get to university, when for some, an important motivating factor (i.e. success) is removed. Others, even very successful ones, do not have a strong interest in mathematics, but see the acquisition of a mathematics degree as an enabler for their future (non-mathematical) careers.

5. The apparent lack of relevance and application of much of the mathematics taught in a context wherein students have been encouraged to study mathematics because of its usefulness in life and in the workplace.

We now consider each of these themes in turn.

The sense of belonging and staff/student relationships

Our starting point is the study Student Experiences of Undergraduate Mathematics (SEUM) (Brown et al., 2005) which examined progress and changing attitudes to mathematics amongst a cohort of well-qualified single honours mathematicians in two research-intensive English universities. Feeling part of a mathematical community emerged as a crucial factor in the student experience, and in the SEUM project, this community focused on a particular physical space within one of the participating universities. Within this space students could not only work together but *“could ‘catch’ lecturers going to and from [their] offices, as well as make formal and informal appointments to discuss various concerns”*. So feeling part of a mathematical community involves both opportunities for interactions with other students and, crucially, with staff.

Croft, Solomon and Bright (2008b), motivated by the SEUM project, believed that there may be scope for improvement in mathematics support beyond year one of a degree programme. In their study, through focus groups they explored which forms of support are accessed by students, which forms they find inaccessible, their views on support provided formally and on the informal networks that they develop with their peers. Focus groups were held in two research-intensive universities A and B. At University A student volunteers were selected from amongst those who had achieved at least an upper second-class score (i.e. greater than 60% overall) in their first year. Two focus groups, each of five students took place in University A. At University B, all second year mathematics students were invited to volunteer and two groups of two and three students respectively were interviewed. All the students in the focus groups in University A were positive about their university experience. On the other hand, when discussing mathematics at university, students in the second made the point that they didn't feel part of the mathematics community:

“Here you're just kind of a number, or one of a crowd. You feel quite anonymous and have all this learning to do”.

Croft et al. (2008b:25)

When asked about their sources of support it became apparent that the support they were obtaining from their peers was highly valued. Students in both universities were asked to whom they would turn first for support:

“yeah I reckon my friends will be the first point of call”.

Croft et al. (2008b:26)

“[working with others] that's the most fruitful situation in which I work – and sit with a group of friends”.

Croft et al. (2008b:26)

Similarly, Brown et al. (2005) reported that students who had more positive attitudes to studying mathematics were those who shared their ideas and problems with other students.

In Mathematical Literacy – Developing identities of inclusion, Solomon (2009) has a chapter devoted to the experiences of undergraduate mathematicians beyond their first year. She reports upon how the students she interviewed positioned themselves in relation to mathematics, their tutors and peers on the course, for example Emma who always positions herself as ‘second-best’ but goes on to describe her tutor’s assessment of her:

“my tutor seems to have high expectations of me...my tutor has more faith in me than I do”.
Solomon (2009:125)

Solomon reports that in her studies, as in other work she refers to, the importance for women of relationships with tutors comes to the fore. Emma goes on:

“It helps because whenever I go to see him when I’m stuck he doesn’t think “well I’m not going to help here – she can figure it out for herself”, he’s always like, “I’m going to help her then she can get there””.

Solomon (2009:126)

Unfortunately, not all students reported the same supportive tutors – in the same study Jess reports:

“my tutor laughs at me”.

Solomon (2009:126)

Rather than being seen as humorous, her fellow students show expressions of sympathy. Even inadvertent or throw-away remarks can inflict damage in ways of which tutors are probably unaware.

Goulding et al. (2003) report a study in which they surveyed 173 students on ten postgraduate teacher training courses (PGCE). These students had attended 65 different universities for their first degree that was either mathematics or one strongly related to mathematics. They were questioned about their undergraduate experiences. Some described the challenge and rigour of university mathematics as interesting and rewarding. Thirty-nine students commented explicitly about their development of understanding during their undergraduate degree. The majority of these students described this as a struggle but one which eventually gave rise to feelings of satisfaction; however, almost as many had been unsuccessful, claiming to have achieved “*little or no understanding*”:

“it was a struggle to maintain enjoyment in the subject when I never felt completely satisfied I understood the concepts in front of me”.

Goulding et al. (2003:370)

Students in this study, as in the others, all recognise the need to work independently, but some felt abandoned, with others relying on informal peer support mechanisms:

“Most lecturers and my tutor were completely unapproachable – you couldn’t ask questions during lectures and felt very alone”.

Goulding et al. (2003:371)

The importance of supportive staff and peer communities should not be underestimated and is a recurring theme in many studies and one to which we shall return.

The quality of teaching

Inglis, Croft & Matthews (2012) surveyed the views of 428 mathematics graduates, 85% of whom had graduated from ‘research intensive’ universities. Their aim was to ask mathematics graduates who had been in the workplace for around two to three years to reflect on their undergraduate experience to ascertain the extent to which the undergraduate curriculum prepared students for the workplace. The issue of teaching quality attracted a number of suggestions although the overall message was variable: many students reported an excellent teaching experience, but others clearly felt there was much room for improvement. The general message was that participants would have liked to receive more in the way of teaching than lecturing, more opportunities for problem solving sessions, and more opportunities to discuss mathematics with their lecturers.

In the survey by Goulding et al. (2003) 23% chose to offer comments about the quality of teaching. Most were very critical of their teachers and their teaching methods, particularly those with an over-didactic style:

“To sit taking meaningless notes all day was just too much...I feel that lectures could have been replaced with handed out notes and some real teaching allowed to take place”.

Goulding et al. (2003:372)

As a consequence of this lack of “real teaching” feelings of frustration were common, with many reporting their undergraduate study as a negative or lonely experience:

“I hated it most of the time...it became difficult to enjoy some of the maths modules if you were struggling and couldn’t get any help”.

Goulding et al. (2003:373)

University mathematics, pedagogic practices and students’ learning styles

In their study of twelve first-year mathematics undergraduate students, also in a (different from SEUM) research-intensive English university, Daskalogianni and Simpson (2002) refer to “cooling-off”. Cooling-off students are those who come to university from school with a positive attitude to mathematics. They find themselves in a learning environment which is very different from the one in which they have previously functioned successfully:

“the experienced mismatch between their beliefs about the nature of mathematics and its rigorous university character soon makes them lose interest in mathematics and develop a negative attitude towards it.”

Daskalogianni & Simpson (2002)

They sum up:

“It is then up to the students themselves [our emphasis] to either recover from that [cooling off] phase or give up and lose not only their interest in mathematics but even their interest in the course and develop a cooling-out behaviour which is very intense in its signs, very difficult to change and might even result in drop-out from the course.”

Daskalogianni & Simpson (2002)

Writing about pedagogic practices Solomon (2009) notes that:

“the fast pace of delivery in lectures meant that [often] the students were simply writing notes without having the time to think about what they were writing. This appears to contribute to a sense of disempowerment.”

Solomon (2009:126)

This is particularly poignant given that lecturers say they want students to be independent, and at the same time (some) would appear to disempower the very students they want to be independent (see Chapter 6 in this book). So what might a good lecture look like? Students commonly cite a desire for a ‘good set of notes’ but Solomon’s student quotes offer some further insight:

“[a good lecture should leave the student] actually wanting to go home and do the homework rather than “I’ve got to do that homework that I know I’m not going to be able to do””.

Solomon (2009:126)

It is not about spoon-feeding or dumbing down. Students expect to have to work for their mathematics degree; they know they are expected to be independent, they do not expect to understand everything in a lecture; however they must be given sufficient support and encouragement to enable them to think that putting in effort on their own is going to be worthwhile. What constitutes ‘sufficient’ support is open to debate, and colleagues will have a range of opinions on this matter, but we would suggest a level of complacency amongst those who argue that there is little room for improvement in learning resources or teaching practices.

Some students find assessment practices too to be a source of alienation. It is interesting here to note the findings from the MUMAP (Mapping University Mathematics Assessment Practices) Project (Iannone & Simpson, 2013) which examined undergraduate mathematics assessment practices scrutinising 1843 modules from 43 degree courses. The project concluded that assessment of university mathematics in the UK is still dominated by closed-book final examination with over one quarter of modules assessed solely by closed-book examination, and about 70% of modules using closed-book examinations for more than 75% of the final module mark.

Students becoming demotivated when no longer successful or interested

Several studies found students who described how much harder they found it to understand new material in year 2. In Croft et al. (2008b) one student mentioned they had

much less supervision, tutorials were different in terms of group size and so they felt there to be less support:

“This is the first year I’ve gone into an exam and had questions I can’t actually answer, because I’ve always been able to do all of the paper. There’s a lot of material this time around, but unless you understand it, it’s not really interesting.”

Croft et al. (2008b:25)

The SEUM project report notes:

“success in the subject at A-level was the major reason for choosing mathematics as a single honours course. When some no longer perceived themselves to be particularly successful there was little to motivate them to continue studying except a need to maintain self-esteem and gain credentials.”

Brown et al. (2005:3)

Doubtless anyone reading this will expect material in the second year of a mathematics degree to become more demanding but the point is to recognise the challenges that this causes for students and to ensure that mechanisms are in place to develop the skills of independent learning that are required, to encourage students to find and develop their own supporting mechanisms and to develop into robust learners.

The apparent lack of relevance

Inglis et al. (2012) citing Thomlinson, Challis and Robinson (2009) compared the outcomes of a survey of the expectations of 223 incoming undergraduates with the results of a survey of 428 graduates. Thomlinson et al. (2009) had found that 93% of incoming undergraduates had expected to develop skill in applying mathematics to real world problems and 95% expected this skill to be important in their future lives. However Inglis et al. (2012) report that only 62% of graduates felt that this had been achieved during their undergraduate studies. One respondent wrote:

“My only issue relates to real world experiences as I feel that this is where mathematics students have been let down. There is little if any mention of how to link mathematics to the real world of work.”

Inglis et al. (2012:19)

This resonates with earlier findings in the SEUM study: with specific reference to the relevance of the content being studied, these students had been led to believe that it would be:

“useful for life in general and for possible future careers”.

Brown et al. (2005)

As the course progressed:

“many of these same students reported their disappointment that the mathematics they were now learning had become so pure as to have no possible application: “I thought I was lucky to realise the importance of maths and to be able to study it at university but now I can’t imagine ever using it in any job I’ll ever do...””.

Brown et al. (2005:4)

However it is important to balance this view with alternative perspectives reported by some. For example:

“it is satisfying to learn mathematics for its own sake – don’t try and make it more applied.”
Inglis et al. (2012:22)

and:

“for me, the most worthwhile aspects of the degree were those modules I took because they interested me. Please include the pure modules that may not seem applicable to most careers.”
Inglis et al. (2012:22)

Of course, the nature of mathematics degrees varies greatly within the sector with some offering courses which are more formal and abstract, some offering quite different proportions of pure and applied modules, and others (many of the newer universities fall into this category) offering courses which are much more orientated to applications and to the workplace (see for example Robinson, Challis & Thomlinson, 2010). Furthermore, many of the exciting real-world applications of mathematics can only be accessed through postgraduate study and perhaps this is not always made clear. However, the point here is that perhaps the particular type of course is not always well communicated to prospective students and a question for the community is how the apparent mismatch can be addressed.

Having briefly reviewed a selection of the literature relevant to the second-year university mathematics experience, the following section considers some ways in which these issues might start to be tackled.

Enhancing the second year experience

In this section we highlight several initiatives that have been instigated to enhance the second year experience. We do not suggest that these provide panaceas for the solution of the problems highlighted, but they provide pointers to possible ways forward. They include creating spaces within which students are encouraged to work together and support each other to develop learning communities, establishment of formal peer support schemes, involving students in curriculum development, encouraging more opportunities for staff/student interactions, and increasing exposure to real-world applications and contexts.

Creating spaces for students within mathematics departments

A finding of the SEUM study related to the extent to which students felt part of a mathematical community. The project noted:

“in one institution, students had their own mathematics study area comprising three sub-areas: an open plan section with tables and chairs; an area with easy chairs and coffee tables; and a cafeteria. Off these areas were staff offices and students could ‘catch’ lecturers going to and from these offices, as well as make formal and informal appointments to discuss various concerns.”

Brown et al. (2005:6)

In the second institution there was limited social space for mathematics (and further, at that institution many students lived at home), and:

“this resulted in a sense of isolation with many of the students reporting difficulty in making friends.”

Brown et al. (2005)

In a survey by Croft, Grove and Bright (2008a) students were asked about the benefits of providing them with social learning space in the department:

“When you go to work [in a dedicated social learning space] the people in there are going to be doing the same stuff as you anyway so you get help with each other.”

Croft et al. (2008a:13)

In this student’s university, space was then found within the School of Mathematics to provide a dedicated area for second and third year undergraduates to work. This reflects an increasing trend by universities, certainly within the UK, and one which seems to be welcomed by students, to provide more extensive social study space for their use.

Peer support

Often friendship groups formed in year 1 are maintained throughout the degree and are mutually supportive. However not all students make friends with students on the same course, and this can be a cause of academic isolation. The formalisation of peer support forms a way in which a department can offer support and at the same time enhance the student experience. This aspect featured in the results of the graduate survey by Inglis et al. (2012). Fifteen out of sixteen unsolicited references to peer support referred to the benefits:

“perhaps we should be allocated to study groups to assist those who don’t naturally find friends on the course and end up working alone.”

Inglis et al. (2012:2)

A peer-assisted learning (PAL) scheme was implemented at Loughborough University in 2011/12 to address the difficulties experienced by second year students. Students who had successfully completed two specific second year modules volunteered and were provided with training to act as ‘Student Leaders’ in weekly PAL sessions. Around half of the second year cohort chose to engage with the scheme and those who attended the PAL sessions had higher achievement in their final module examinations even after controlling statistically for prior attainment and lecture attendance. Of course, not all students wanted to attend PAL sessions, some because they preferred to work alone and could succeed independently. Those that did attend found the PAL sessions to be informal and welcoming and involved discussion of mathematical topics that had previously been suggested by the PAL participants.

The preceding discussion highlights the non-homogeneity of student groups in terms of their preferred learning styles, and whether they prefer to learn mathematics with others or on their own. Attempts to address problems of disengagement and alienation must be sensitive to these differences and try to present a portfolio of opportunities sufficient to meet the needs of diverse cohorts.

Involving students in expert communities

In recent years there have been calls to the higher education community to involve students more in the planning and design of courses (see for example Kay, Marshall & Norton, 2007). The SYMBOL (Second Year Maths BeyOnd Lectures) project based at Loughborough University in 2011 did just that. Four students who had successfully completed the second year of the single honours course in mathematics were employed as interns for a six-week period during the summer. Their focus was upon two historically-problematic second year mathematics modules. They had several roles:

- To act as intermediaries between their peers and staff gathering information about teaching strategies that the students perceived to work well, suggesting improvements, and alternative ways of doing things.
- To work with staff, scrutinising the modules' resources and suggesting ways in which these might be improved.
- To develop further resources of their own, under the guidance of the module leaders, which would be (and were) made available to future cohorts.

Findings have been reported in Croft, Duah and Loch (2013) and include the ways in which the interns were inculcated into the mathematical community and the nature of their relationship with staff changed for the better. Through their mutual engagement staff and interns engaged in a mathematical discourse in ways that normal lectures and tutorials do not make possible: as well as building better relationships with staff and becoming part of a mathematical community the interns involved reported deeper mathematical understanding and confidence in their own abilities. Staff acknowledged that students can bring a new dimension to teaching and learning discourses:

“[Students probably have] more knowledge of where exactly the students are struggling. Pointing exactly at the right places where the lecturer might think the students have understood when they haven't actually because the feedback loop is not as closed as it should be.”

Croft et al. (2013:1051)

In this sense, as well as providing opportunities for some second year students, we see the initiative as encouraging continuing professional development of staff and a means for at least some improvement in alignment between student and staff expectations.

In a more generic context while employability audits of undergraduate programmes have existed for some time, these have typically been undertaken by academic staff rather than students. The University of Exeter, in a student-led project undertaken in collaboration between students, graduate employers and staff (Cooper, 2012), carried out an audit of the extent to which support for the development of employability skills is embedded within the mathematics, computer science and engineering degree programmes. The process was overseen by a paid focus group of students working over a period of six weeks to audit current provision and make recommendations for how employability skills might be enhanced. All mathematics and engineering students (some 300 in total) from across all

year groups were invited to participate through a questionnaire to obtain a wider student perspective; 49 students responded.

Through a blog established in support of the project, updated by both staff and students, their views on the process were captured, and this was further supplemented by the creation of a 'Creative Learning Journey' which formed a multimedia staff and student perspective on the process. While established to help students develop their employability skills, through both undertaking a project and enabling revisions to existing provision to be suggested (for example one outcome has been the design of a mathematics group project module), students have been able to make a direct contribution to their learning experience which they have valued:

"Its [sic] been a very productive 6 weeks and we feel the contributions we have made will be valuable in improving the degree programme."

Prince & Neale (2011)

Through the National HE STEM Programme, the Student-Led Employability Audit was extended to five further universities, and at the University of Manchester this was implemented to audit undergraduate degrees within the School of Mathematics. A similar outcome to that at Exeter was that students produced a report, recommending both major and minor changes to the provision they experience, some of which were implemented in time for the 2012/13 academic year. The key outcome relevant here is the extent to which students felt involved in the process of developing and enhancing their own learning, recognised their role within the process, and had opportunities to engage in dialogue with staff about this.

While these two activities form specific examples, they represent a more general point of being approaches that enable students to contribute to the development of their own learning and feel that they are making a contribution to enhancing the practice of their department. It might be argued that the immediate benefits of such activities are limited to the relatively small number of students involved and do not transfer to the wider student body. But in fact we believe that some benefits do transfer, although perhaps in more subtle ways. Firstly, there is little doubt that this professional development experience for the small number of staff directly involved has given them new insights into the difficulties and perceptions of the students; in turn this is likely to impact gradually on their own teaching practices. There are also the benefits perceived by other (non involved) students in that the department is seen to be listening to their concerns, taking these seriously through meaningful action, and that modifications might ultimately be made as a consequence of their work.

Developing (informal) staff student communities

A number of mathematical sciences departments have established 'Maths Arcades' – drop in sessions where students can play a range of strategy games and puzzles with each other and with academic members of staff (see for example Bradshaw & Rowlett, 2012). Maths Arcades aim to simultaneously support those learners who may be struggling and test and challenge more confident learners. One of their key features, however, is to enable greater staff-student interaction in an informal, but mathematical, context.

While Maths Arcades are a new initiative, certainly within the UK, initial evaluations have shown that one of the key aspects students value is the increased opportunities they provide to interact with members of academic staff:

“I like to go to the Maths Arcade because all of my tutors attend it”.

Bradshaw (2012:12)

“[It is] a really good way to meet people and get to know the lecturers in a more informal environment”

Bradshaw (2012:12)

And staff report complementary views:

“I thoroughly enjoyed playing against the students where they had as much chance of winning as I did. It allowed us to interact in a more relaxed but equally intellectual way.”

Levesley (2012:23)

Maths Arcades have prompted students who have not engaged with drop-in mathematics support to seek support from tutors, and increased engagement between student cohorts has been reported by staff:

“... the more that students see mathematical conversations happening between staff and students, the more they realise that they too can ask questions... The games were used and maths conversations were started (“can I ask you a question?”) by students who had not attended the traditional drop in sessions. There was also interaction between staff and second year students and between the year groups.”

Barton (2012:27)

As a consequence of running Maths Arcades, universities have recognised the concept of games and puzzles to enhance student problem solving skills, and as such, have implemented these into the curriculum:

“In addition, the puzzles and games have been incorporated into a second year mathematics module that aims to develop problem-solving skills. Students study the various games and puzzles, in particular by playing the games against other students, and the discussion of the games themselves leads to understanding of the strategies required to play effectively.”

Chadwick (2012:17)

Context and problem based learning

We have already commented that many, but by no means all, mathematics graduates would welcome increased exposure to more real-world applications of mathematics. There is no doubt that formulating and solving problems is a core part of all undergraduate mathematical sciences provision, but what is less well embedded, particularly when compared to disciplines like, for example chemistry (Belt & Overton, 2007), is the context within which mathematics is applied to solve problems (context based learning). Many of the recruitment talks and events students experience while making their university choices highlight examples of how mathematics can help solve key global challenges or,

for example, where mathematics can be applied in appealing fields such as sport or music technology, but quite often this is the last time such applications will be mentioned during their university studies; for some, this can lead to a mis-match between their expectations and the realities of studying mathematics.

Some mathematics departments have sought to implement ways for students to experience mathematics within a range of applied contexts. Placements, whereby students spend a period of time working within business or industry as part of their degree programme, have been offered for many years but as noted by the Science Council (Mellors-Bourne, 2011) while there is not generally an issue in the supply of placement opportunities an *“increasingly significant proportion of sandwich course students are reluctant to undertake long placements (partly because many HEIs charge at half fee level)”*. Despite this, placements offer a range of benefits including not only the chance for the student to develop essential employability skills, but they can also increase student motivation by demonstrating how they can apply their skills and knowledge successfully in business and industry. In the past, industrial placements would typically have been a year in duration but there now exist a range of models which allow students to access placement opportunities in a more flexible and tailored manner ((see Mann, 2012) for a review of models in mathematics).

Where it has not proved possible or practicable to implement placement models, mathematics departments have found alternative mechanisms for students to gain more context-based experience. A number of departments have, for many years, offered postgraduate level industry study groups whereby representatives from industry work with mathematicians in a structured manner on current workplace problems. Variations upon this model have been adopted by a number of mathematics departments where undergraduate students work collaboratively on employer-defined problems and case studies as part of their programmes of study. Students not only engage with current and meaningful real-world problems, but employers also typically have a role in contributing to delivery and supporting assessment, which means students develop relationships with employers in a manner that allows them to discuss the relevance and applications of mathematics. Recognising that not all mathematics departments have access to a wide range of employers, there has been significant work in developing a ‘bank’ of freely accessible industrial problems which academics can use with their students (see for example, Benjamin, Homer, Lawry & Rossiter, 2012). Such forms of problem based learning are more interactive, representing a move towards experiential rather than didactic learning, and as a consequence students have increased opportunity to engage with members of staff.

Concluding remarks

In this Chapter we have looked particularly at published evidence which suggests that the academic experience of many, but by no means all, second year mathematics undergraduates is less rewarding than it could be. Doubtless some of the issues we highlight affect students in other years and in other disciplines too. However our focus here has been the second year experience. We have suggested several ways in which this experience could be enhanced. We have provided details of these not as a prescription but rather with the intention that they encourage reflection by mathematics staff on practices within their own departments:

- Are there issues like the ones described here within my own department? How would I know?
- Is there scope for improvement of practice within my own department?
- Are the full range of students that we recruit best served by our teaching and learning practices, by our curriculum and by the supporting infrastructure we provide?
- When we promote our courses to prospective students are we clear about the nature of these courses and particularly what makes them distinctive in our institution?
- What steps, if any, are individuals and departments in other universities taking to address these issues?

If individuals, groups of staff and whole departments reflect seriously on these questions, and practices evolve accordingly, the experience of all their students will be enhanced. As many of the chapters in this book affirm, there is a growing corpus of literature and many colleagues and interest groups to support staff in this journey.

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