

Improving Mathematics Education

what can we learn from 25 years of mathematics support?

We are deeply honoured and delighted to receive the IMA Gold Medals 2016. For the first time, the IMA has awarded Gold Medals to individuals working in the field of *mathematics education*. We believe this is timely recognition of the challenges facing those charged with inspiring the next generation of mathematicians and the many more non-mathematicians who will need to use mathematics and statistics in an increasingly wide range of occupations.

The branch of mathematics education in which we are well known is *university-wide mathematics and statistics support*. It is for work in this area that the Medals have been awarded. Here we provide a brief history, dating back to the early 1990s, of what has become known as the *mathematics problem* – the broad meaning of the term being that incoming undergraduates, at that stage studying primarily engineering and physical sciences, were under-prepared for the mathematical demands of university courses. We explain our role in the development, across the sector, of *university-wide mathematics support* as a positive response to this problem.

Recently, many disciplines other than engineering and the physical sciences have become more quantitative. The corresponding increase in the quantitative nature of many university courses has not coincided with an increase in preparedness of students for taking such courses. The *mathematics problem* has broadened and continues to affect yet more students. The need for mathematics support is as pressing today as it was when we first became involved.

Perhaps surprisingly, many students who self-select to use mathematics support are single and joint honours mathematics students. This inevitably raises the question ‘Why?’ – given that these students are sufficiently well-qualified mathematically to have been admitted to a mathematics degree and, unlike students in other disciplines, *have specifically chosen* to study the subject at university. Drawing upon data from our own research and from the National Student Survey, we highlight some of the reasons why this is so. We explain what mathematics support can provide, which some elements of traditional university mathematics teaching do not. We pose some questions for academics to consider as university mathematics teaching evolves to embrace and enthuse future generations of students.

Why and how mathematics support developed

As noted above, the phrase the *mathematics problem* came into common usage in the 1990s and referred to student under-preparedness for the mathematical demands of their courses. Newspaper articles with headlines such as *Engineers Unable to Bridge the Maths Gap* [1] appeared. Numerous reports from professional bodies and learned societies went beyond rhetoric and provided evidence of the scale of the problem. Prominent amongst these were *Tackling the Mathematics Problem* [2], and *Engineering Mathematics Matters* [3].

Initial responses were piecemeal, the most common being the development of mathematics support within universities. (Throughout, the term *mathematics support* will be used as shorthand for the more correct *mathematics and statistics support*.) By

mathematics support, we mean provision additional to lectures, tutorials and problems classes; its aim is to improve the performance of students, *particularly those for whom mathematics is not their main subject of study*. Students from a wide range of disciplines may access mathematics support; originally, the most frequent users came from mathematically-rich disciplines such as engineering and physics but, nowadays, students from a greater variety of disciplines including nursing, business and social sciences take advantage of the support offered.

Mathematics support takes various forms: drop-in centres, appointments-based services, pre-session courses and online resources. In recent years, the drop-in centre has become the dominant form of provision. Coventry University (then Coventry Polytechnic) was one of the first institutions to establish a large-scale support facility in 1991. The Mathematics Learning Support Centre at Loughborough University followed in 1996. Both the Loughborough and Coventry Centres, working together, have provided models and resources that have been adopted or adapted at other universities throughout the UK and beyond.

In the late 1990s, Mike Savage (University of Leeds) organised a summit for the mathematics community to make an evidence-based case to address the problem. An outcome was the report *Measuring the Mathematics Problem* [4] which drew on the analysis of trends in A-level Mathematics based on diagnostic testing undertaken at Coventry University [4, pp.6–10]. The report affirmed that the need for mathematics support was not confined to post-92 universities – the challenge was sector wide.

Following the publication of *Measuring the Mathematics Problem*, we were members of a small delegation that met with the Minister for Lifelong Learning and Higher Education, Margaret Hodge, in 2001. It is believed that the report, the subsequent ministerial meeting together with lobbying by at least one prominent vice-chancellor led to the establishment by the government of the Smith Inquiry into Post-14 Mathematics Education. The subsequent report, *Making Mathematics Count* [5] made a series of recommendations, many of which were acted upon by government. Together the two reports were influential. The first stated that

Acute problems now confront those teaching mathematics and mathematics-based modules across the full range of universities [4, p. ii].

Prompt and effective support should be available to students whose mathematical background is found wanting [4, p. iv].

This recommendation was reinforced by the Smith report:

Higher education has little option but to accommodate to the students emerging from the current GCE process [5, p. 95].

Importantly, these reports had a significant effect on legitimising mathematics support. The latter affirmed that the need to provide support was not just because an institution had necessarily recruited students who were in some sense ‘substandard’ and not suitable for higher education but because of deficiencies in the pre-university education system.

... The *mathematics problem* has broadened and continues to affect yet more students ...

Good mathematics support centres share common characteristics. A centre should provide a location, resources and activities designed to support a student's learning of mathematics. Suitable tutors are key to success. Support should be non-threatening and non-judgemental – recognising that, for many students, taking that first step to enter the centre might be intimidating. Mathematics support is frequently managed and delivered by staff from the mathematics department – this was the case in the early Coventry and Loughborough centres.

As mathematics support evolved the nature of provision diversified. For some, the facility is managed by a member of the mathematics department but the tutors are postgraduates; elsewhere, often institutions without mathematics departments, provision is located within a central study skills unit; sometimes there is a sole individual responsible for delivering support. Having tutors with the right mix of skills and experience – mathematical, pedagogical, and possessing an empathetic approach – is essential if students are to thrive. Drop-in centre work is demanding: students come from a wide range of courses; there is usually not much time to make a judgement about the nature of the student's difficulties and the level of help required.

In the early days not all academics were enthused by the notion; neither were all suited to working in a support centre. Dr Joe Kyle (University of Birmingham), in *Responding to the Mathematics Problem*, wrote

... Looking back, I probably regarded mathematics support as a form of cottage industry practised by a few well meaning, possibly eccentric, individuals, who may themselves have been hard pushed to offer a credible rationale for this work ... [6, p. 103].

Nevertheless, the mathematics support community persevered. Surveys conducted between 2001 and 2012 recorded the growth of provision. The latest, in 2012, revealed that out of 97 respondents, 79 universities (81%) have some form of mathematics support [7].

In 2002 a successful bid to the Higher Education Funding Council for England (HEFCE) and the Gatsby Foundation from the universities of Loughborough, Coventry and Leeds established a virtual mathematics support centre so that students anywhere could take advantage of resources developed at the lead centres. Today **mathcentre** (www.mathcentre.ac.uk) remains a widely used repository housing over 1000 items, including 100+ hours of video tutorials designed to ease the transition into mathematics at university.



The sigma CETL and Network

In 2004, HEFCE launched its Centres for Excellence in Teaching and Learning (CETL) programme. This was a competitive programme where universities could nominate practice which they believed merited *Centre for Excellence* status. A submission from Loughborough and Coventry Universities nominating their work in mathematics support was successful and '**sigma** – Centre for Excellence in University-wide Mathematics and Statistics support' was created. CETLs received significant levels of funding during 2005–2010. Although much of the impact of many CETLs was primarily within their own institutions, from the outset, **sigma** had wider ambitions. Written into **sigma**'s proposal was that it would provide funding to support the establishment of mathematics support at three other universities.

By 2010 a vibrant community of mathematics support practitioners had been established, becoming the **sigma** Network. The National HE STEM Programme and HEFCE's fund for Strategic & Important Vulnerable Subjects provided further funding from 2010–2016. Some of **sigma**'s achievements include:

- assisting, through funding and mentoring, the establishment of 36 support centres during 2005–2016, the majority still active today.
- supporting colleagues to establish the Scottish Mathematics Support Network (2008) and the Irish Mathematics Learning Support Network (2009).
- projects to develop support for students with disabilities and specific learning differences.
- paid student internships for projects concerned with promotion, resource generation and research.
- production of resources and workshops for training tutors.
- the reincarnation of the publication *MSOR Connections*.
- an annual conference since 2006.
- good practice guides such as *How to set up a Support Centre* and *Gathering Feedback*.
- numerous research publications.

Why the need for support continues

In the light of the Smith Report and the government's response, it might be thought that the *mathematics problem* had been solved and the need for mathematics support would be waning. However, this is far from the reality experienced on the ground.

The Nuffield Foundation report *Is the UK an outlier: An international comparison of upper secondary mathematics education* [8] examined the proportion of the cohort who continue to study mathematics after the age of sixteen. It showed that in England, Wales and Northern Ireland less than 20% of students study any mathematics post-16. However, in 18 of the 24 developed countries in the study the figure is over 50%, in 14 it is over 80% and in 8 it is 100%. This situation has serious ramifications when these students come to university.

In 2011, the Advisory Committee on Mathematics Education published *Mathematical Needs: Mathematics in the workplace and in higher education* [9]. As a consequence of the woefully low participation rate in studying mathematics post-16, it addressed the number of students entering higher education under-qualified mathematically concluding:

We estimate that of those entering higher education each year, some 330,000 would benefit from recent experience of studying some mathematics (including statistics) at a level beyond GCSE, but fewer than 125,000 have done so [9, p. 1].

Newer reports continue to flag the challenges. In the biosciences increasing quantification of the discipline is causing concern:

Many biological science graduates have not studied mathematics beyond 16 ... their understanding of statistical techniques is low ... demand for statistics skills will increase [10, p. 25].

... there is also an urgent need to raise the mathematical and computational skills of biologists... [11, p. 15].

In Social Science quantitative demands are increasing and students need to be better prepared for competing internationally. The British Academy position statement *Society Counts: Quantitative Skills in the Social Sciences and Humanities* [12] emphasised this:

The UK is weak in quantitative skills, in particular but not exclusively in the social sciences and humanities ... another reason for the poor skills of undergraduates is the dearth of academic staff able to teach quantitative methods [12, pp.1–4].

The level of concern expressed by so many different national bodies is compelling evidence that the *mathematics problem* has not been solved and until it is the demand for mathematics support is certain to continue.

Mathematics students and mathematics support

As noted earlier, a significant user group of support centres comprises those students studying single or joint honour mathematics. Loughborough University's Mathematics Education Centre Annual Reports show that typically 25% of students who visit support centres are mathematics students. Centres in many other universities report broadly similar percentages. To unpick some of the reasons for this we turn to findings from our own research and the National Student Survey (NSS) in 2016. (Findings from other years are similar.) The NSS is an annual survey of finalists (across all institutions and subjects). Students respond to a series of statements about their experience using a 5-point Likert scale to show their level of agreement. The percentage of students indicating some level of agreement is recorded and the results

enable comparison across the 21 subject areas defined by high level JACS codes.¹

When compared with students studying subjects other than mathematics, the mathematical sciences perform very well on some items, not so well on others, and very poorly on yet others. The items upon which mathematical sciences is the highest ranking subject are:

- Assessment arrangements and marking have been fair (87%)
- Any changes in the course or teaching have been communicated effectively (88%)
- The course is well organised and running smoothly (89%)

We argue that these items are *process* focused statements and it is probably not surprising that the mathematical sciences perform well. On the other hand, some not-so-good results are found when considering *teaching* focused statements:

- Staff are good at explaining things (15th out of 21 subjects)
- Staff have made the subject interesting (18th out of 21 subjects)
- Staff are enthusiastic about what they are teaching (14th equal out of 21 subjects)

Given the wide reach of mathematics and the potential to enthuse students with modern, relevant applications, some readers of *Mathematics Today* may find these results surprising.

Mathematical Sciences students indicate the lowest level of agreement of all subjects in respect of two *personal development* focused statements:

- The course has helped me present myself with confidence (69%)
- My communication skills have improved (68%)

Across all students who completed the survey (i.e. from every subject) 81% and 84% respectively agreed with these statements. Given the importance attached to employability, and particularly how young people are often persuaded to study mathematics because of the consequent career opportunities, these results might cause the academic mathematics community to reflect on aspects of the role of a mathematics degree.

Research undertaken with Yvette Solomon (Manchester Metropolitan University), gathering data from mathematics undergraduates, offers some insight into the ways in which support centres can ameliorate this situation, particularly with regard to perceived shortcomings in teaching [13–14]. Some sample quotes from students (cited in these papers) talking about their experience of mathematics at university are indicative:

If you've got someone who's going to patronise you if you're totally wrong then you'll be reluctant to shout out [14, p. 571].

On the other hand, the staff/student power dynamic is reconfigured in mathematics support centres:

If you go to their office ... You're going into *their* office, whereas maths support is neutral ground for everybody ... it doesn't belong to anybody [14, pp. 579–580].



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In your little group you can have a lecturer sit down and explain it to you which might be better for some people, because some people might not want to ask a question in front of the whole lecture whereas they will in the maths support centre [14, p. 580].

The availability of the physical space and its configuration promote collaboration:

You sit next to people at round tables and you can explain things in a way that makes sense to you [13, p. 427].

It appears that many mathematics undergraduates do not wish to adopt a solitary, competitive approach to studying mathematics but instead value the undergraduate communities of practice that support centres can encourage:

I used it [the maths support centre] a lot because a group of us who tend to get fairly good marks used it. Other people came in to work with us and got the help and so on ... it developed a real upspin, it was really kind of, in a sense, the place to be ... [13, pp. 428]

For many undergraduates, support centres appear to have an impact on discourses of ability and learning: they lead in particular to an appreciation of, and emphasis on, collaborative work and consequently to a shift in attitudes towards university mathematics as a community of enquiry as opposed to an individual performance-oriented pursuit.

Conclusion

We have shown that mathematics support developed as an urgent response to a very real problem and that the need for it remains high and is unlikely to disappear. Unfortunately, in the current economic and political climate funding to sustain a well-resourced national network of support practitioners is unlikely to be forthcoming. Nevertheless, our work has successfully established a community determined to continue. The **sigma** Network endures as a professional association managed by an elected steering group. The annual conference, a continuing series of workshops and resource-sharing all provide strength for this community. Three special interest groups, *Employability*, *Statistics* and *Accessibility* will take forward specific agendas.

We close with some further remarks from *Responding to the Mathematics Problem* illustrating a lasting shift in mindset:

... Looking back, I probably regarded mathematics support as a form of cottage industry practised by a few well meaning, possibly eccentric, individuals, who may themselves have been hard pushed to offer a credible rationale for this work ...

... Now only a few years on, we see that the concept of mathematics support has not only become firmly embedded in UK Higher Education, but colleagues have moved on to gather data on the way students use such resources and look for optimal strategies for the delivery of this support, and this is perhaps the most convincing evidence of acceptance. Mathematics support came of age in the first decade of the 21st century. What might once have been described as a cottage industry now plays a respected and widely adopted role in Higher Education [6, pp. 103–104].

The problem may not be solved, but mathematics support provides a proven way of mitigating some of its worst effects.

Acknowledgement

We acknowledge numerous academic and support staff, students, agencies and professional bodies with whom we have worked. Through their enthusiasm, expertise and dedication, hundreds of thousands of students have been supported. We would like to feel that we are accepting the Medals on behalf of all these people. Through their hard work and commitment mathematics support has gathered significant momentum and yielded the positive benefits it has today. Thank you.

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Notes

- 1 The Joint Academic Coding System (JACS) is a way of classifying academic subjects. See <http://tinyurl.com/JACS-classification>.

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