Increasing the Supply of Mathematical Sciences Graduates

A Community-wide Programme of Activity

Michael Grove and Duncan Lawson

In August 2006 the Higher Education Funding Council for England (HEFCE) approved funding for a £3.3 million pilot programme of activity designed to increase and widen participation within the mathematical sciences. The moremathsgrads proposal was developed by the Heads of Departments of Mathematical Sciences (HoDoMS), the Institute of Mathematics and its Applications (IMA), the London Mathematical Society (LMS), the Maths, Stats & OR Network, and the Royal Statistical Society (RSS) and followed a period of community-wide consultation [1]. Many national organisations have given their support to the Project and, to date, 22 individual HEIs have expressed a desire to be directly involved in its activities.

Within this paper, we will present evidence gathered during the development of the project proposal thereby providing an overview of the current situation in the mathematical sciences; we will review the aims and objectives of the project; and conclude by outlining the activities that will take place throughout the pilot phase of activity.

Evidence of a Decline

Mathematics is a compulsory part of the National Curriculum for all Key Stages. This can be a double-edged sword in terms of increasing the popularity of mathematics. On the one hand, it means that all school students have to continue to study mathematics until age sixteen. But, on the other hand, this can have a negative effect as many students perceive mathematics to be hard, boring, and not relevant to their future and not leading to employment. Furthermore, whilst many students find mathematics hard, there is clear evidence that the current curriculum fails to stretch and inspire the more able students [2].

Although many disciplines in Higher Education (HE) either require or prefer A-level mathematics as an admission qualification, the number of entries to A-level mathematics has shrunk from nearly 85,000 in 1989 to around 53,000 in 2004. This decline has occurred at a time when the total number of A-level entries has increased significantly, and so consequently the percentage of mathematics entries compared to the total A-level entries has fallen over this time from 12.8% to 6.9% [3].

A recent report by the Qualifications and Curriculum Authority (QCA) [4] noted that around 50% of the GCSE cohort achieve grades A* to C, a figure of approximately 300,000, in 2004. However, only around 63,000 of these students went on to take AS level in mathematics, and, of these, only 41,500 sat the A-level. In other words, only 14% of those achieving GCSE grades A* to C in mathematics go on to take an A level in the subject.
This decline in the popularity of mathematics has important implications for other subjects in Science and Technology as mathematics underpins disciplines such as Engineering, Physics and Chemistry. Indeed, those involved in the teaching of Physics and Engineering within HE have spoken of a ‘mathematics problem’ for some time, particularly at the transition to university study [5, 6].

Data obtained from the Higher Education Statistics Agency (HESA) shows that the overall number of full-time UK and EU starters studying the mathematical sciences has fallen from 9196 in 1998 to 7985 in 2004, a drop of approximately 13%. The decline is also evidenced by the 2005 HECFE report of the Chief Executive’s Advisory Group on Strategically Important and Vulnerable Subjects [7] which noted a fall in activity of 9.3%, or 1800 FTEs, as measured from 1999-2000 to 2003-2004. It should be noted that there has been considerable confusion surrounding the number of undergraduates within the mathematical sciences over the last few years. This uncertainty has arisen as a result of changes to the coding system used by HESA in 2002-2003. A recent study by the LMS [8] has identified these anomalies, and confirms that the number of students studying programmes within the mathematical sciences has fallen significantly over recent times.

**Breadth of Student Participation within the Mathematical Sciences**

Whilst the statistics outlined in the previous section indicate that the mathematical sciences have become generally less popular subjects in the student population as a whole than many other subjects, there are particular student groups where this unpopularity is even more marked.

The recent QCA report on participation in mathematics at A-level [4] notes that: ‘there is less success in recruiting girls to AS and A-level mathematics than boys’. An analysis of the HESA data confirms this continues at undergraduate level. In 2003-2004 the proportion of females in the mathematical sciences was 38%, similar to the figure in 1999-2000. It should be noted that there has been considerable confusion surrounding the number of undergraduates within the mathematical sciences over the last few years. This uncertainty has arisen as a result of changes to the coding system used by HESA in 2002-2003. A recent study by the LMS [8] has identified these anomalies, and confirms that the number of students studying programmes within the mathematical sciences has fallen significantly over recent times.

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Total students</th>
<th>White</th>
<th>Asian (inc. Chinese)</th>
<th>Black</th>
<th>Other</th>
<th>Unknown</th>
</tr>
</thead>
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<tr>
<td>Maths</td>
<td>7985</td>
<td>74.8</td>
<td>14.5</td>
<td>3</td>
<td>2.9</td>
<td>4.8</td>
</tr>
<tr>
<td>Total HE</td>
<td>342769</td>
<td>77.0</td>
<td>9.8</td>
<td>4.6</td>
<td>3.2</td>
<td>5.4</td>
</tr>
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Table 1 – Percentages of different ethnic groups for full-time UK and EU starters in 2004

Participation can be seen to be lower for both the Black and White ethnic groups, but higher for Asian groups; this is due to the high popularity of the mathematical sciences amongst Chinese and Indian students. The ethnicity distribution has remained stable from 1998 to 2004, despite the number of full-time UK and EU starters decreasing by 13% over the same period.

A report published by the Royal Society [9] in April 2005 investigated the attainment of pupils at different stages in mathematics. This showed clear differences in level of performance of different ethnic groups. For example, in 2002, 67% of the 600,398 eligible pupils achieved level 5 or above at Key Stage 3 in Mathematics. For the 498,614 students from White ethnic groups 68% achieved level 5 and above, but for students who are from the Black Caribbean (8040), Black African (7003), Pakistani (13,713) and Bangladeshi (5,141) ethnic groups the percentages were 52% or lower. Chinese (1,962) and Indian (13,949) students had much higher percentages at 87% and 74% respectively.

The HESA data show that the students studying the mathematical sciences full-time tend to be younger than the average for students on all subjects. Some students progress through school mathematical examinations at a fast pace and so enter higher education at an earlier age. At the other end of the age range, however, the numbers of older students studying the mathematical sciences are relatively low when compared to the total HE population. This is shown in Table 2.

<table>
<thead>
<tr>
<th>Ages</th>
<th>Total FT students</th>
<th>Under 18/Unknown</th>
<th>18-21</th>
<th>22-30</th>
<th>31+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maths</td>
<td>7985</td>
<td>4.1</td>
<td>85.7</td>
<td>6.1</td>
<td>4.1</td>
</tr>
<tr>
<td>Total</td>
<td>342769</td>
<td>2.6</td>
<td>78.7</td>
<td>12.5</td>
<td>6.2</td>
</tr>
</tbody>
</table>

Table 2 – Percentages of full-time UK and EU starters by age group in 2004

The situation has remained relatively constant with respect to age group throughout the period 1998-2004, with the exception of a small decline since 1998 of the proportion aged 22 and over (down to 10.2% from 11.4%). Participation within the mathematical sciences for those over the age of 22 (10.2%) is considerably lower than the average for HE in general (18.7%).

Carrying out a similar analysis on the data for part-time students shows that the age distribution of this group of learners aligns closely with the age distribution of all part-time students (Table 3):

<table>
<thead>
<tr>
<th>Ages</th>
<th>Total FT students</th>
<th>Under 18/Unknown</th>
<th>18-21</th>
<th>22-30</th>
<th>31+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maths</td>
<td>961</td>
<td>1.1</td>
<td>8.3</td>
<td>35.5</td>
<td>55.0</td>
</tr>
<tr>
<td>Total</td>
<td>60770</td>
<td>0.5</td>
<td>9.7</td>
<td>33.5</td>
<td>56.3</td>
</tr>
</tbody>
</table>

Table 3 – Percentages of part-time UK and EU starters by age group in 2004
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Comparison of the data in Tables 2 and 3 shows that only 1.6% of part-time students study the mathematical sciences compared to 2.3% of the full-time cohort.

Analysis of the HESA data by socio-economic classification shows the profile of entrants to full-time degrees in the mathematical sciences to be heavily weighted towards the higher socio-economic classifications, with less that 25% of students in groups 4-7.

In summary, the mathematical sciences appear to be particularly unpopular with female students, with certain ethnic groups, with mature learners, with part-time students and with those from certain socio-economic groups. There is therefore considerable potential to increase enrolments in the mathematical sciences in higher education from these groups.

The Aim of the moremathsgrads Initiative

The moremathsgrads initiative aims not only to increase the number of undergraduates studying the mathematical sciences in England, a need clearly identified, but also to widen participation from groups of learners who have not traditionally been well represented in Higher Education. If there is success in widening participation in the mathematical sciences in Higher Education, then it follows that there will also be success in increasing the number of mathematical sciences graduates; the two aims of the Project are intrinsically linked.

The project will therefore seek to: address the gender imbalance that currently exists in the mathematical sciences; encourage more students from the Black African, Black Caribbean, Pakistani and Bangladeshi groups to study the mathematical sciences; encourage more returning adult learners, particular those studying part-time to choose the mathematical sciences; and, to increase the number of learners from the lower socio-economic groups.

In addition to increasing the number of mathematical sciences graduates, the project will also have an impact in other important areas that will be of real benefit for society, for example:

- Increasing the number of students taking mathematics at A-level (or an alternative level 3 qualification), particularly amongst students who have not achieved the highest grades at GCSE.
- Increasing the mathematical achievement of students who may decide to study other STEM related programmes within HE.
- Increasing the number of specialist mathematics teachers in schools by increasing the number of undergraduate students who wish to train as teachers.

In order to meet its overall aims, the Project has four objectives and these may be conveniently expressed as four themes. The themes contain aspects of support for school and college students to gain, and then sustain, their interest in the mathematical sciences and to encourage them to pursue their further study within higher education:

1. **Careers Theme**: Improve understanding of the wide-ranging applicability of mathematics and the breadth of career opportunities open to graduates from the mathematical sciences.

2. **Student Theme**: Help school and college students to understand the purpose of mathematical study, to enjoy mathematics, to be confident about meeting challenges in the subject, to realise their potential in mathematics and to raise their aspirations about further study of mathematics.

3. **Teaching Theme**: Contribute to the development of teachers’ enjoyment, confidence and knowledge of mathematics and its applications so that they can help stimulate interest in further study of mathematics in their students.

4. **HE Curriculum Theme**: Increase the scope of the mathematics curriculum for HE nationally in order to allow real choices for a wide range of students.

The Implementation of the moremathsgrads Initiative

The activities of the moremathsgrads project will take place within three regions for an initial period of three years: the West Midlands, Yorkshire and Humberside, and London. Three lead universities are involved from each region, and these are Coventry University, the University of Leeds, Queen Mary, University of London. Sheffield-Hallam University will lead the HE Curriculum Development theme. The project will work with 7 schools and colleges within each region; these institutions will be chosen based upon widening participation criteria in consultation with Aimhigher and Action on Access.

Strategic advice and guidance to the Project, along with responsibility for the management of its day-to-day activities will be provided by the Maths, Stats & OR Network at the University of Birmingham.

The Project will develop and expand links between schools, colleges, careers organisations, universities and employers. Engagement with regional and national employers is therefore crucial if the project is to succeed. Four major employers have already expressed their support and commitment to this proposal: Rolls-Royce PLC, Thales, Qinetiq and the Ford Motor Company. In addition, further employers will be identified via the networks of the organisations involved in the development of this proposal, along with HE alumni networks, the Sector Skills Councils and local SETPOINTs.
The Careers Theme Explained

There is substantial evidence that shows that when students are making their choices with regard to A-levels and university study they are not aware of the types of careers that follow from studying the mathematical sciences [4], or indeed of where mathematics is used within the workplace [10]. In addition, there is anecdotal evidence that there is a lack of understanding on the part of teachers and careers advisors of the range of careers available in industry and commerce for people with a mathematical sciences degree. This view was confirmed during discussions with several teachers during the consultation phase of the proposal development.

While there may be little understanding of the range of careers available in industry and commerce for people with a mathematical sciences degree, employment prospects for mathematical sciences graduates are very good, particularly for students with wider skills who can communicate mathematical ideas and concepts to non-mathematical people. A study at the University of Newcastle, reported in the Times Education Supplement [11], compared the incomes and educational backgrounds of 4,500 people and concluded that having a Mathematics A-level can increase long-term earning power by 7 to 10 per cent.

The moremathsgrads initiative will develop a series of high quality careers resources for use by students, teachers and careers advisors, promoting the diverse range of employment opportunities open to graduates from the mathematical sciences. Employers and universities will have direct input into the creation of these materials. The resources will be made available nationally on the Council for Mathematical Sciences (CMS) www.mathscareers.org.uk website, which will also undergo extensive redevelopment as part of the project. In addition, careers events within local schools, and this forms an expansion of the Institution Masterclass series, and will be primarily facilitated by members of university mathematical sciences departments, although teachers will be encouraged to offer similar events themselves. The resources developed to run the enrichment and enhancement classes will all be made available on the Project website, www.moremathsgrads.org.uk, for use by those running similar events nationally. Larger events will be offered for both students and teachers within universities demonstrating ‘real world’ applications of mathematics.

To ensure students receive comprehensive and accurate careers advice, the moremathsgrads initiative will engage directly with careers advisors and teachers. The Project will run yearly training events, and will work with national careers organisations, including Connexions, to share the resources produced and improve the standard of careers advice that students currently receive with regard to the mathematical sciences.

The approach proposed builds upon the recommendations from a National Institute for Careers Education and Counselling (NICEC) report [12] on choosing science at age-16. The moremathsgrads initiative will: strengthen the links between mathematics departments and careers departments and their advisors; offer events designed to stimulate interest and to inform students about mathematics while they are still in school; and offer opportunities for students to have contact with holders of some higher-level jobs relating to mathematics, or those who have studied mathematics.

The Student and Teaching Themes Explained

The student and teaching themes are intrinsically linked, and so here we choose to discuss them together. Whilst the student theme addresses current students, in order to achieve long term embedding and sustainability of key elements of the Project, it is necessary to engage teachers fully with these elements. This will enable teachers to become more effective in promoting the mathematical sciences to their students. Indeed, a justification of this approach is highlighted by the Ofsted report on Secondary education published in 1998 [13], which commented:

‘When teachers are thoroughly in command of their subject, they are able to adapt their teaching to the responses of the pupils, to use alternative and more imaginative ways of explaining, and to make connections between aspects of their subject and with pupils’ wider experiences, so capturing their attention and interest. The teacher’s ability to answer spontaneous questions is an important factor in generating enthusiasm for the subject.’

Clearly there will be a degree of overlap with the remit of the recently established National Centre of Excellence in the Teaching of Mathematics (NCETM), particularly in the nature of the support offered to teachers. The project will support, and provide access to, the work of the NCETM in developing both the subject and pedagogical knowledge of teachers of mathematics.

The Project will offer a series of enrichment and enhancement events to students within the pilot regions; the aim of which is to enthuse and inspire. The format of such events will be based upon the successful Royal Institution Masterclass series, and will be primarily facilitated by members of university mathematical sciences departments, although teachers will be encouraged to offer similar events themselves. The resources developed to run the enrichment and enhancement classes will all be made available on the Project website, www.moremathsgrads.org.uk, for use by those running similar events nationally. Larger events will be offered for both students and teachers within universities demonstrating ‘real world’ applications of mathematics.

Undergraduate students will be engaged to assist teachers within local schools, and this forms an expansion of the successful ambassador type schemes that are already available. The Project will also work to promote the range of provision available to adult learners, such as the Open University Mathematics modules, to enable them to study the mathematical sciences within higher education.
The HE Curriculum Development Theme Explained

The HE Curriculum Theme will have a number of strands of activity. In one strand, it will address issues of breadth of provision and its attractiveness to a wide range of potential learners. It is important to understand why mathematics is unpopular amongst certain groups of students. For example, work in this theme will explore whether the types of courses and mode of study available in the mathematical sciences (rather than the subject itself) act as a disincentive to mature or part-time students.

Another strand will be to explore the learning, teaching and assessment methods in university mathematical sciences departments to determine if changes might be made to better support students throughout their studies. In recent years, many universities have made significant investment in support provision [14] particularly aimed at non-specialist students. However, there is emerging evidence that points to a problem amongst specialist mathematical sciences students during the later years of their programmes [15]. One way to increase the number of mathematical sciences graduates is to increase the success rates of those that are currently recruited and so work in this area will contribute directly to the achievement of the project’s principal aim.

A further element of work in this theme will address the issue of ‘graduate skills’ within the undergraduate cohort [16]. Notwithstanding the key fact that, from the employers point of view, the mathematical sciences are a highly desirable discipline, it is nonetheless important to ensure that graduates have the appropriate generic skills that employers want in addition to the special skills that mathematical sciences graduates bring.

Activities within the HE Curriculum Development Theme will not be restricted to the regional partner institutions but will involve other mathematical sciences departments throughout the country that are keen to explore this crucial element of increasing the attractiveness of the mathematical sciences in higher education.

Conclusions

The activities to be undertaken as part of the moremathsgrads initiative have been designed to produce the following key outcomes:

- A positive change in the perception of mathematics amongst school students and in the way in which schools engage with HE and the mathematical sciences.
- An improved understanding of the pathways available for students who wish to study the mathematical sciences in HE.
- A greater awareness and understanding of the applications and opportunities offered by a study of the mathematical sciences.

These will lead to:

- More HE students within the mathematical sciences;
- More HE students within the mathematical sciences who are women, students from the lower socio-economic groups, minority ethnic students and adult learners;
- More students who are women, students from the lower socio-economic groups, minority ethnic students and adult learners enrolled upon HE courses with a significant mathematical component, for example, Economics, Physics and Engineering;

Monitoring and evaluation will form an ongoing process throughout, and activities, events and resources will be developed and tailored in response to this process. The moremathsgrads Project will run until July 2009, and regional activities will commence in Spring 2007.

Although activities are focussed within three regions, it should be stressed that any resources produced by the Project will be made available nationally on the two Project websites: www.moremathsgrads.org.uk and www.mathscareers.org.uk.

Acknowledgments

We would like to acknowledge and thank those who have worked hard to develop this proposal. In particular the Steering Group who oversaw the development of the proposal, and Diane Crann and Lis Goodwin for all of their efforts in organising the consultation phase, in assembling the evidence and in drafting the proposal that was submitted to HEFCE.

References


11. ‘A level Maths equals money’ Report in TES Feb 19 1999 on research by Anna Vignoles and Peter Dolton at the University of Newcastle.


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