The London Mathematical Society

Doctoral Training in Mathematics in the UK

A position paper of the London Mathematical Society

TABLE OF CONTENTS

Executive summary	2
Core Criteria	3
Background	3
Intake	4
Fees and Funding	4
Training	7
The PhD Examination	9
Spatial distribution	9
Subject distribution	10
Destinations and sustainability	10
Conclusion	11

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EXECUTIVE SUMMARY

1. Doctoral graduates in the mathematical sciences are vital to maintain the UK's world class research base and for their wider contribution to the UK economy. Between 400 and 450 doctorates are awarded in the mathematical sciences in the UK each year; this number needs to be raised to 500 to maintain the academic community and meet the UK's demand beyond academia. To complete the pathway, 100 postdoctoral positions are needed each year by the mathematical sciences community.

2. A first class degree (or equivalent) should normally be expected for admission to a PhD. We would also expect a large proportion of students to have moved institution since their undergraduate degree and the quality of the locally-trained and migrant students to be the same.

3. The Research Councils' approach to funding doctoral training in mathematical sciences is broadly appropriate.

- The level of the Doctoral Training Account should not be eroded in favour of further Doctoral Training Centres
- Peer review is vital in deciding Doctoral Training Grant allocations for mathematics
- We fully endorse the decision of EPSRC to report the allocation to mathematical sciences in the Doctoral Training Account as a separate line.

4. The breadth and depth of PhD training everywhere in the UK must compare favourably to that available at peer institutions in the other leading mathematical nations.

- Mathematical sciences students should have eight years of study[1] from the beginning of their undergraduate career to the end of their doctorate
- Doctoral students must have secured funding for four years
- All PhD students should have access to a wide range of taught courses using real or virtual trans-institutional communities where necessary.

5. Every UK PhD thesis in mathematics should contain publishable original work to compete internationally. Students should also demonstrate genuine fluency in their area of research, the ability to do original work and an appreciation of the important ideas across a wider range of mathematics.

6. Doctoral students should be distributed widely across the UK. At the same time:

- All PhD students should be embedded in a community of peers that has sufficient mass to stimulate and maintain a culture of solidarity and excitement within each field and across mathematics
- Stable mechanisms must be developed in order to foster and maintain such communities
- The entry-standard of PhD students and the level of achievement demanded of them should not differ markedly across the UK.

7. A lack of accurate data on the distribution of PhD students by subject area could lead to skills shortages in core areas of the mathematical sciences. Accurate data on this must be collected, collated and maintained.

[1] This extending where appropriate to nine in Scotland

Doctoral Training in Mathematics in the UK

1 Core criteria

Doctoral graduates in mathematical sciences are the life-blood of the UK's world class research base and vital for their wider contribution to the UK economy. To maintain this, UK doctoral training in mathematics must fulfil two key criteria:

1. *The breadth and depth of PhD training everywhere in the UK must compare favourably to that available at peer institutions in the other leading mathematical nations. Anyone awarded a PhD in the UK should be comfortable with the main ideas of a wide spectrum of mathematics, should be expert in an active field of research, and should have demonstrated the ability to do original research.*

2. *The number of PhDs awarded in the UK each year must be sufficient to replenish the academic community in this country and, simultaneously, meet the UK's demand beyond academia for mathematicians trained to PhD level.*

   The mathematical community recognises and encourages the free flow of talented young mathematicians around the world but believes that the UK's long-term interests will be ill-served by a systemic dependence on overseas-trained mathematicians.

2 Background

The document is written from the point of view of the London Mathematical Society so that 'the community' refers to the academic community of mathematical scientists. We recognize explicitly that this community is a part of wider society, has responsibilities to it and could not exist without it. Similarly, we recognize that the the community could not exist without funding bodies or research councils, and our recommendations are intended to take into account existing practical and political constraints.

Our data comes from two sources, the Higher Education Statistic Agency (HESA) and the outcome of the 2008 Research Assessment Excercise (RAE2008); because of their different definitions it is sometimes hard to relate the two. We also refer to the EPSRC-sponsored 2004 International Review of Mathematics (IRM2004).

The number of doctorates in mathematical sciences awarded annually in the UK is between 400 and 450 (HESA). The resultant stream of highly qualified graduates is vital to the health of the discipline. Not only does it sustain future generations of researchers in our universities, but it also provides significant numbers of highly trained employees for other sectors. This document provides an overview of the nature of the cohort of students, their sources of funding, the training they receive, and their destinations after graduation. It also discusses some of the steps required to guarantee sustainability of the community and competitiveness of the UK doctoral training in the mathematical sciences.

3 Intake

According to HESA data from 2007/8, about half of students registered for a research degree in mathematics were UK domiciled and one sixth from other EU states. (This is in line with the average across all academic disciplines.) Over the period 2003-7, 23% of UK domiciled doctoral graduates in mathematical sciences were female and 7% were registered as part time students. The low proportion of female students is a continuing concern. Across all academic disciplines, amongst students who started doctoral studies in 2004/5, 44% were studying at a UK HEI in the previous year. Of those, 64% either had a first class degree or a Masters level qualification. Although universities may use their discretion in deciding whether candidates are suitable for research training, EPSRC guidelines indicate that an upper second class honours degree (or a combination of qualifications and/or experience at that level) should be a normal requirement for admission to a doctoral training programme. In 2008/9, 1750 1st class undergraduate degrees and a further 1320 higher degrees (excluding PhDs) in mathematical sciences were awarded across the UK, suggesting that there is a large pool of highly qualified potential PhD students.

> **Recommendations:** *We recommend that a first class degree (or equivalent) should normally be expected for admission to a PhD, but we would not wish to see this expectation become an exclusionary rule. In a healthy doctoral programme we would expect a large proportion of students to have moved institution since their undergraduate degree, and we would expect the quality of the locally-trained and migrant students to be the same.*

4 Fees and Funding

Overview

Sources of funding can be broadly divided into UK Research Councils, the European Union, Industry, Overseas Government and Self-Funded. Many universities also have Graduate Scholarships and in 2004/5, this represented the major source of tuition fees for 24% of starting doctoral students (across all academic disciplines). Depending on the source of funding, grants can be awarded to the institution, the supervisor or the student. A large proportion of graduate students undertake a limited amount of teaching both as a form of training and as a source of additional income.

In mathematical sciences, the EPSRC is the largest single funder of PhDs, and much of our discussion therefore discusses EPSRC policies. Nontheless BBSRC, NERC and STFC fund some students, and our general conclusions do not depend on the research council concerned. According to the 2008/9 annual report, the EPSRC Mathematics Programme was supporting (or partly supporting) 710 doctoral students. The funding plan for 2010/11 includes £10 million for Doctoral Training. The national minimum stipend for EPSRC-funded PhD students is £13,590 (tax free) for the academic year 2010/11, although (as we explain below) some graduates will receive more than this.

Fees

The maximum annual postgraduate fee payable by UK research councils was £3,390 in 2009/10 and many universities set this as the fee for home/EU students. In Oxford and Cambridge there is an additional College Fee of about £2000 per annum, but research councils do not provide extra funds to cover this. Overseas student fees are highly variable across institutions and courses. (For example, the University of Oxford alone currently advertises twenty different fee bands for its postgraduate courses, with mathematics set at £12,200 in 2009/10.) Universities UK publishes an annual survey of tuition fees for international students.[1] Fees are usually payable for three years,

[1] A comprehensive survey of fees at UK HEIs can also be found at http://web.mac.com/mikereddin/PublicGoods/Education.html

but this is by no means universal. The 2008 National Student Forum commented in its annual report on the lack of certainty over the level of tuition fees over the duration of the course.

Doctoral Training Grant

Most EPSRC studentships are funded through Doctoral Training Grants (DTGs). The procedure for allocating these is different in mathematical sciences from other disciplines (in most areas an algorithm based on research grant income is used to calculate the DTG, but grant income is not a reliable indicator of quality or activity in mathematics). Each year EPSRC convenes a peer review panel to agree, on the basis of specified criteria, how the money available to mathematical sciences should be divided between institutions. Currently the criteria are 2008 RAE score (35%), EPSRC grant income (15%), breadth and depth of training (30%), and student quality and completion rates (20%). The statistical information available is placed in context by a written submission from each deparment. In 2010/11 a total of about £7.8 million will be distributed in this way. It is important to note that this money is awarded to institutions, *not* to departments. The combined DTG across all disciplines awarded to an institution is called its Doctoral Training Account (DTA). (In 2008/9, EPSRC released two years worth of commitment to DTAs, totalling £167 million.) Until 2009, the EPSRC informed institutions of the earnings through research grants by department that had contributed to the DTA allocation, along with certain consequences. In 2010 this was changed, and information is now limited to a breakdown of the DTA by each contributing programme. However, the total amount awarded for mathematical sciences *is* still recorded separately in the award letter. Institutions are not obliged to follow the EPSRC split in distributing the DTA funds to departments and, indeed, the change in the award letter is intended to encourage institutions to think more strategically about the internal allocation of DTA money, which is likely to give the health of the discipline a lower priority. In 2009/10, at least one institution decided to award none of the substantial mathematical sciences DTG to its mathematics department. The late stage in the year at which the DTA allocation is announced (usually April) is also a matter of serious concern.

DTGs may be used to fund the full cost of a studentship for UK students and the fees component of studentships for EU students. They also contain an element to cover incidental costs of research projects such as skills training and attendance at conferences. In accordance with recommendations from the 2001 'SET for Success' (Roberts) report, funds have been provided separately for transferable skills training (see §5). Departments have some flexibility in how they use their DTGs. For example they may fund a student for anywhere between three and four years, the average being 3.5 years, and provided they pay at least the EPSRC minimum stipend they may choose how much to pay students. This feature is designed to address difficulties of attracting and retaining students in vulnerable sub-disciplines. When a student is eligible for a full award, at least 50% of the total cost of the studentship must be met from the DTG of a single research council, but the remainder can be made up from other sources.

Other vehicles for EPSRC funding

There have been three other avenues through which EPSRC supports PhD students. First, individual researchers can apply for funding for PhD students as part of a (typically) larger research grant proposal to work on a specific project. Funding for these 'project studentships' can requested for up to four years. The student eligibility requirements are less restrictive than for DTG funding, and allow the recruitment of international students. In 2009 there were 70 project students receiving funding through EPSRC grants from the Mathematical Sciences Programme. Second, EPSRC has for many years offered Collaborative Awards in Science and Engineering (CASE) to support projects linked to external organisations. These come in two varieties, Industrial CASE and Mathematics CASE studentships. Subject to the same rules as outlined above for the DTG, students receive funding for a full EPSRC studentship for 3.5 years and companies provide additional top-up funding (which for Industrial CASE must be at least a third of the EPSRC funding and for Mathematics CASE a somewhat lower partner contribution). A small sum is also paid to

the supervisor's host university. The student must spend at least three months at the company during the period of the studentship. The EPSRC 2008/9 annual report shows 11 Industrial CASE awards in mathematical sciences departments; most of these are distributed through companies or other organisations (including the Knowledge Transfer Network for Industrial Mathematics) for direct allocation. The remainder respond to an EPSRC call for proposals or are conversions of standard DTA studentships. In 2010, EPSRC is only accepting proposals from companies wishing to establish new collaborations and it anticipates making about 40 awards across all of its subject areas. Mathematics CASE awards, of which there are some 30 distributed annually, are allocated to universities alongside the DTA allocation process. As a final point, EPSRC indicates to universities that it wishes at least 10% of all studentships supported through the DTG to be CASE awards.

Centres for Doctoral Training

Finally, EPSRC also funds 'Centres for Doctoral Training'. Originally concentrated on research at the interface of distinct scientific disciplines, the concept has recently been extended and there are now three centres in the mathematical sciences. These 'securing the future' centres, announced in 2009/10, comprise the Cambridge Centre for Analysis, the Lancaster University centre for Statistics and Operational Research, and the Mathematics and Statistics Centre for Doctoral Training at Warwick University. The Centres for Doctoral Training use the model of a four year doctoral programme. Typically, the first year involves intensive training and research 'mini-projects' and work towards a PhD dissertation only begins after 12-15 months. An aim of the CDTs is to enable students to make better informed choices when they select a research sub-area and supervisor, and to have greater breadth and depth of mathematical understanding before their research project commences. The eligibility rules for CDT funding are the same as for the DTGs. The CDT model has some attractions. However, in the context of very limited funding for doctoral training, CDTs raise a number of concerns for the mathematical sciences community: they concentrate funding in a small number of institutions and they allocate funds disproportionately to specific subdisciplines. (For example the Cambridge centre is seeking an initial cohort of up to fifteen students.) There is no doubt that there are areas in need of special support, but this should be introduced steadily, to ensure availability of supervisors and, of course, sufficient suitably qualified and motivated students. The secondary effect of starving other areas is inevitable when funding is limited.

Overseas students

Funding for overseas students is scarce. The Overseas Research Students Awards Scheme (ORSAS), set up by the Secretary of State for Education and Science in 1979 to attract high-quality international students to the United Kingdom to undertake research is being phased out over the 2009/10 and 2010/11 academic years. The Scottish Funding Council is now running a rebranded Scottish Overseas Research Students Award Scheme (SORSAS), which covers the difference between the tuition fee for a UK/EU graduate student and that chargeable to an overseas graduate student. In the 2009/10 academic year, the budget for the scheme was £2.8 million. There are limited funds to attract students from certain countries (sometimes also restricted by subject and/or institution), for example Commonwealth Scholarships, Dorothy Hodgkin Postgraduate awards and Marshall Scholarships. The UK Council for International Student Affairs (UKCISA) provides a wealth of information, including some insights into Immigration Rules and the British Council website has an extensive list of funding opportunities. The Committee of Professors of Statistics and the Operational Research Society websites provide information specific to probability and statistics and to operational research respectively. The overall picture is complicated and it seems to be largely a matter of luck whether or not suitable funding opportunities will exist in a student's chosen institution. There can be little doubt that the UK is missing out on a pool of highly talented students. The relatively low level of UK government funding for international doctoral researchers is in contrast to the increasing level of activity of competitors, including other EU ocuntries where fees are not usually charged, for example Finland and Sweden. Moreover, many European countries are developing doctoral programmes in English, with the aim of attracting international researchers.

We would hope that the number of UK students choosing to pursue doctorates overseas would be mirrored by a similar number of talented overseas students coming to the UK. The loss of the ORSAS scheme has dealt a serious blow to this aspiration.

Summary

There are three natural models for the distribution of funding for doctoral research. Money can be allocated to the student, the potential supervisor or the institution. Current arrangements place an emphasis on the second and third, perhaps for practical reasons.

> **Recommendations:** *We believe that an approach to funding based on a blend of the above three models such as that currently used by the research councils, is appropriate for the mathematical sciences. We do not wish to see the level of the DTA eroded in favour of further DTCs. We strongly support the use of peer review in deciding DTG allocations for mathematics. We believe that the four criteria used by the peer review panels are appropriate, but we would like to see the weighting of 'student quality' increased. We fully endorse the decision of EPSRC to report the allocation to mathematical sciences in the DTA as a separate line.*

5 Training

The 2004 International Review of Mathematics (IRM) reported that

> The panel found that a typical UK PhD programme is of shorter duration and more narrowly focused than those in most other countries. As a result, new PhDs from the UK usually have less breadth and experience than their peers from other countries and have difficulty competing for research fellowships and academic posts.

This echoed Sir Gareth Roberts' 2002 review, 'SET for Success', which recommended that 'The length of a doctorate should be increased to an average of 3.5 years.' It is still the case that the length of the doctoral training is very varied, but EPSRC DTG funding assumes a 3.5 year average. HEFCE (the Higher Education Funding Council for England) also currently provides funding for home/EU postgraduate research students directly to universities based on an average 3.5 years study for a full time research degree (although the funding is profiled over 3 years for full time and six years for part time students). In agreement with IRM2004 (Section 2.2), we believe that, for the majority of students, 4 years will be required to complete a PhD competitive on the international market. This would bring UK into line with the Bologna agreement, which recommends 8 years between the start of an undergraduate degree and award of a PhD. Because of the UK funding mechanisms, this would mean 4 (or 3+1) years at the undergraduate level[2], and 4 years on a PhD. *We strongly support this guidance.*

The most significant part of a student's time of study is spent in doing mathematical research, partly in the passive sense of reading preexisting work, but mostly in experiment, calculation and development, leading to an original synthesis, written up as a thesis. It is this that leads to the distinctiveness of doctoral level skills compared to graduate skills. The basis of this aspect of PhD training is the relationship with the supervisor, structured around regular meetings. For most students, the early part of their studies is designed to prepare them for this work.

While the academic community may regard doctoral students as the power base of research and the feedstock for the next generation of researchers, this only accounts for a small proportion. Doctoral training should take account of the needs of the employment that students are likely to find. The Roberts report recommended that

[2]In some institutions in Scotland the undergraduate training is 4+1 years, reflecting the different secondary education system.

> Major funders of postgraduate researchers should make all funding conditional on postgraduate researchers' training meeting stringent minimum standards... This should include the provision of at least two weeks' dedicated training a year, principally in transferable skills.

Research councils currently provide about £22 million per year of 'Roberts skills money' towards the cost of two weeks dedicated training for each student each year. Roberts funds have been confirmed until the 2010/11 academic year, but then cease in the current form. All universities offer generic skills training to their doctoral students, but we also highlight the enormous transferable skill component intrinsic to the process of completing a PhD. The length and depth of the project requires exceptional commitment and the ability to seek and organise information and to explain it in both verbal and written form is a model for what is required in a wide variety of employment.

Even for those not enrolled in a DTC, it is usual for first year students to attend some mathematical lectures relevant to their studies. In response to the concerns of the 2004 IRM relating to the breadth and depth of knowledge of their subject of UK PhDs, EPSRC funded six Taught Course Centres (TCCs) to provide graduate level courses in mathematical sciences. They are organised around consortia of universities. Three of these centres exploit video conferencing technology to enable audiences in all participating universities to take part in lectures. Additional material is available via the web. Centres in Statistics and Operations Research offer residential courses while the London Taught Course Centre takes advantage of the accessibility of de Morgan house by using the LMS as a base for its courses. The first courses were offered in October 2007 and the TCCs are now under review. They have revolutionised PhD training outside the main centres, making it possible to offer a balanced and extensive suite of courses even at smaller institutions. We regard them as an essential component of PhD training and are committed to their continuation.

The TCCs cater largely for first and second year PhD students. More specialised courses are available through the LMS/EPSRC short courses. These are one week residential programmes, centred around three (usually six hour) lecture courses, supplemented by tutorial sessions. They are organised by the LMS, through the Research Meetings Committee (RMC). The current contract with EPSRC, which commits the Society to providing an average of 6 courses per annum, runs until October 2011. The RMC receives (and solicits) proposals for courses from the community which are then sent to international referees for comments. In choosing courses, the RMC tries to ensure a balance between different areas of mathematical sciences. In addition, the RSS runs instructional courses in statistics. The LMS/EPSRC short courses have proved an efficient and effective way of providing high quality courses for graduate students across the UK and, again, we are committed to their continuation.

The combination of the TCCs and the EPSRC/LMS short courses has had a huge impact on doctoral training in the UK. However, there is still some concern that students are not achieving the same breadth and depth of mathematical knowledge as their peers in other European countries or in the US. In both continental Europe and the US, there are instructional meetings aimed at advanced graduate students and postdoctoral researchers. Many of these meetings are open to UK students, but mechanisms need to be found to secure funding for their participation, and the UK community should aim to play a more active role in organising such events.

An important component of doctoral training is learning to communicate complex concepts. Many students benefit from participation in postgraduate seminars and reading groups. Mathematical writing is learned by a combination of instruction and supervised practice. Finally, after suitable training, students usually play a part in teaching in their department.

> **Recommendations:** *In line with the Bologna standards, and IRM2004, British students in the mathematical sciences should normally have eight years of study*[3] *from the beginning of their undergraduate career to the end of their doctorate. All PhD students should be funded for four years. Any student enrolled in a PhD programme in the UK should have access to a coherent programme of taught courses.*

[3]This extending where appropriate to nine in Scotland.

We acknowledge that implementing this recommendation without reducing numbers poses problems for funding; nonetheless, we reiterate that a 4 year PhD is necessary for international comparability.

6 The PhD examination

In the UK, the PhD is not classified, but instead is examined on a pass/fail basis (although, exceptionally, a student may be awarded a Masters by Research in lieu of a doctorate). The decision to award a doctorate is based on the submitted thesis and an oral examination. There are generally two examiners, one from the student's own institution and one from another (not necessarily UK) institution. The guidelines for examiners typically say that the PhD should be judged on the basis of 'what may reasonably be expected of a capable and diligent student after three or at most four years of full-time study'. In order to calibrate this for the modern needs of the mathematical sciences, we propose a more rigorous and better tailored criterion.

The main shortcoming of the definition, which is designed to encompass all disciplines, is that it fails to recognise that if a UK doctorate in the mathematical sciences is to be internationally competitive, it must culminate in the writing of a thesis that contains publishable original work. Moreover, the student should, in the course of the oral examination, demonstrate fluency in an area of modern mathematics and appreciation across a wide range of mathematics. Beyond this, they should have acquired, during the course of their training, a wide range of transferable skills (including presentation, teaching, organisation and critical judgement). We believe that it is vital that these requirements be fulfilled, and that it is unrealistic to expect it to be achieved in less than four years.

> **Recommendations:** *The standard expectations for the award of a PhD should be commensurate with the expectation that students are funded for four years. Every PhD thesis should contain publishable original work. All students should be required to demonstrate genuine fluency in their area of research and an appreciation of the important ideas across a wider range of mathematics.*

7 Spatial distribution

The British Council searchable 'Education UK' website can be used to find a listing of doctoral training opportunities in mathematical sciences in the UK. A search on full time research degrees in mathematics leads to close to 250 results. Although this figure includes MPhils, it nonetheless suggests that there is a bewildering choice facing a prospective doctoral student, both in terms of subject area and geographic location.

In reality, the distribution of doctoral students across the country is very uneven. In 2007 there was a total population of about 1200 graduate students distributed across the approximately 40 institutions that submitted returns to RAE 2008, giving an average of 30 graduate students per institution. However, bearing in mind the existence of several departments with many times this number, and the fact that this figure covers the whole breadth of mathematical sciences, we see that some students are being trained in relative isolation.

Individuals and institutions need graduate students if they are to maintain a healthy research environment and students in turn need a vibrant research environment if they are to thrive. The TCCs have gone some way to mitigating the isolation of students in some of the smaller centres, but we would like to emphasize the importance of direct contact between students which leads to graduate communities that transcend institutional boundaries. In particular we would like to see mechanisms to facilitate further collaboration between institutions, for example through provision of informal workshops, courses or postgraduate seminars. Students can then be trained in an (extended) environment containing a 'critical mass' of peers working in their immediate field while maintaining graduate communities in a wide range of institutions. The community does not

feel that concentration of students in a small number of centres can go further without seriously damaging the health of the subject in some geographical regions.

> **Recommendations:** *All PhD students should be embedded in a community of peers that has sufficient mass to stimulate and maintain a culture of solidarity and excitement within each field and across mathematics. Stable mechanisms must be developed in order to foster and maintain such communities at a metauniversity level in order to accommodate students in smaller institutions. The standard of entering PhD students and the level of achievement demanded of them should not differ markedly across the UK. Taking due account of these requirements, we wish to see as wide a distribution of postgraduate students as possible in the UK.*

8 Subject distribution

At present, the distribution of PhD students by subject is determined by three main factors. First, a large proportion of the best undergraduate students are concentrated in a small number of institutions, and hence are exposed to the subjects most strongly represented there. Second, there are more studentships in subjects well represented in institutions with more studentships. Third, students are drawn to supervisors with a wide reputation. None of these is intrinsically bad, but they risk reinforcing historical trends and responding slowly to future needs. The academic community should monitor the commercial and academic needs in different subject areas.

It is extremely difficult to obtain reliable data on the distribution of PhD students by subject area and we strongly recommend that steps should be taken to gather such data. At present there is no means, other than via anecdotal evidence, for the community to obtain an overview of the subject areas represented by the next generation and we risk overlooking skills shortages even in core parts of the discipline.

> **Recommendations:** *Accurate data on the subject areas of PhD students must be collected, collated and maintained.*

9 Destinations and sustainability

According to the annual HESA surveys for 2004-2008, 42% of doctoral graduates in mathematical sciences find work in the education sector, 34% in finance, business and IT, 18% in other sectors and about 6% unemployed.[4] Research occupations accounted for 30% of respondents employed in the UK, of which about two thirds were research staff rôles in higher education.

The value placed by employers outside academia on the doctorate can be seen from the fact that in 2006, six months after graduation, the average salary of someone with a first degree was £22.5k, whereas the average for someone with a PhD is £27k. According to a HoDoMS/CMS survey, in 2006, within academia, 40% of PDRAs (postdoctoral research assistants) had a PhD from a UK institution, rising to 55% of unpromoted academic staff and 70% of promoted academic staff.[5]

Evidently PhDs are highly sought after. Industrial advisors tell EPSRC that maths doctoral graduates are highly valued for their analytical skills, but would be even more in demand if they had greater openness of mind and a 'multidisciplinary' mindset. Nonetheless we do not have figures for how many PhDs industry would like trained. Instead, we take here the replenishment of academics as a measure of demand. Based on the first destination data gathered for the 2004-2008 HESA surveys, we estimate that about 10% of PhDs go on to be lecturers in Higher Education. According to HEFCE, 1933 FTEs were RAE returned across mathematics in RAE 2008. Assuming a 40 year career, that means 50 new academic staff each year. This means that the UK needs to produce

[4] This data is based on employment status in January for all those students graduating in the previous calendar year and so the surprisingly high number reported as unemployed is probably misleading.

[5] We do not have any corresponding post-RAE2008 data, but we conjecture that this could be markedly different, with significantly larger numbers of PhDs from overseas among academic staff.

around 500 PhDs in the year in order to maintain the steady state. Of course, some of those academic posts will be filled by individuals with PhDs from overseas, but, assuming that the UK PhD is competitive, we would expect similar numbers of UK PhDs to be taking academic positions overseas. In most subjects, lecturers are not appointed directly from their PhD. Allowing for some attrition at the postdoctoral level, we note that the calculation above suggests that we also need of the order of 100 postdoctoral positions starting each year.

> **Recommendations:** *In order to provide a sufficient number of suitably trained people for the non-academic community, and to replenish the academic community, the UK university system needs to provide secure funding for 500 PhD places in the mathematical sciences each year. It also requires 100 postdoctoral positions starting each year.*

Once again, we acknowledge that our estimates of what is required for sustainability poses a problem in funding the positions. If we do not find a solution to the problem, we must accept the inevitability of decline.

10 Conclusion

Among the policy statements included above, by far the most important is this: in order to meet the core criteria articulated at the beginning of this document, secure funding must be available for approximately 500 PhD awards each year; each award must fund *four years* of study if our doctoral students are to reach the level of their international peers.

Moreover, all students should have access to a wide range of taught courses. There should be no compromise on this issue in smaller institutions. In order to avoid further concentration of students in a handful of departments, stable mechanisms are needed to provide trans-institutional communities and to provide courses for students in smaller institutions.