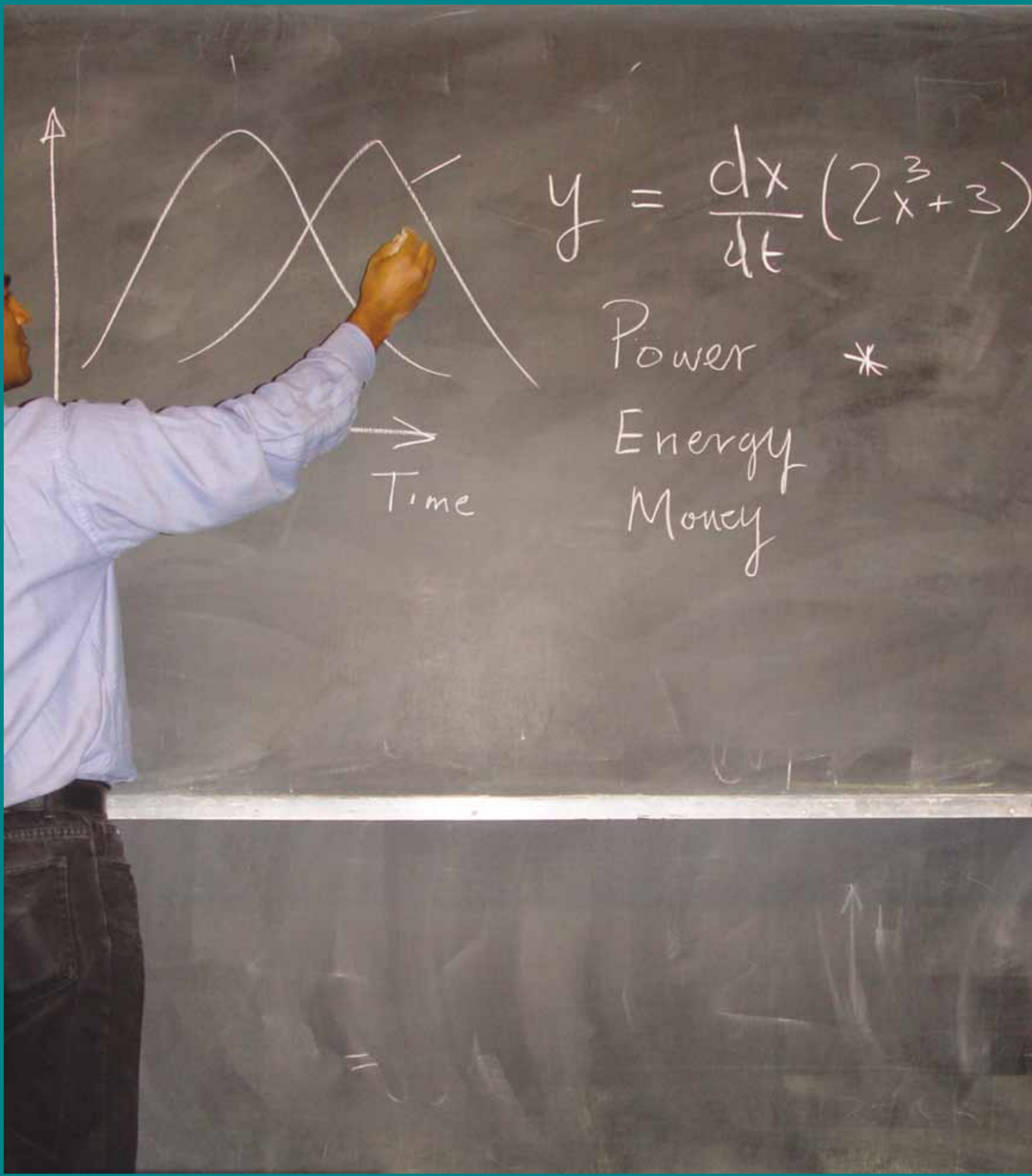
THE ROYAL SOCIETY
CELEBRATING 350 YEARS

A higher degree of concern



Policy document 02/08
January 2008
ISBN 978-0-85403-673-8
£39

This report can be found at royalsociety.org

twenty ten and beyond | 350 years of excellence in science

Professor Judith AK Howard CBE FRS
Chair of the Royal Society Higher Education Working Group

I am pleased to present this report on science, technology, engineering and mathematics higher education in the UK. It follows an earlier report which focussed on first degrees, looking at postgraduate degrees and making broader recommendations which will allow the UK HE system to be fit for purpose into the middle of the next decade and beyond. I have thoroughly enjoyed exploring these complex and difficult issues with my colleagues on the working group, as indeed I have enjoyed interacting with others from all areas who are interested in the questions we have been addressing. Maintaining the output of well trained and flexible science, technology, engineering and mathematics professionals is of integral importance to the UK's economic and social development. The key issues to have come from this current study are:

- Courses in core subjects need to be sustained at all levels
- The UK should allow (and properly fund) a norm of eight years from starting as an undergraduate to finishing with a PhD. Within this framework, there should be flexibility of timescales and mode of study to suit students and the subject matter
- The UK should be defended as a destination of choice for higher education studies

Professor Martin Taylor FRS
Physical Secretary and Vice President of the Royal Society

It is vitally important that we all work together to enthuse and educate the young in science; and that we make sure that the next generation of British scientists are amongst the very best in the world. Our report provides a wealth of data which we have used in formulating our recommendations and vision for the future. We also hope these data will be of great value to others for evidence based decision making. This report is the culmination of a major area of work for the Society, and it represents a great deal of effort undertaken by Professor Howard and her colleagues. I would like to add my thanks to them for their efforts and to commend this report to all those who are interested in the future of UK higher education.

THE ROYAL SOCIETY

CELEBRATING 350 YEARS

A higher degree of concern

ISBN 978 0 85403 673 8

Typeset by The Clyvedon Press Ltd, Cardiff, UK

A higher degree of concern

Contents

Summary

The Higher Education system underpins the UK's ability to do well as a nation. In the context of an increasingly competitive and inter-connected global economy, this means that HE must equip students individually with the knowledge, skills and aptitudes to hold their own with the best in the world. At the same time HE must provide the basis for a skilled workforce that meets the UK's needs quantitatively and qualitatively. This report highlights important recent trends in the teaching and research training functions of HE and steps we must take, urgently, to ensure that it delivers these requirements over the next decade.

Students are mobile, especially at graduate level. There is global competition to attract the best students onto masters and doctoral courses. The UK competes successfully: numbers of non-UK masters students at UK universities have nearly quadrupled in the past ten years and now account for over half of all masters students, while numbers of non-UK doctoral students have more than doubled. These non-UK students contribute hugely to the quality of the UK HE experience, and constitute a remarkable opportunity for long-lived UK influence.

In order to remain attractive in this market, the UK must align itself more closely to the Bologna vision, to which 46 European countries (including the UK) have now subscribed. Bologna sets an internationally recognised benchmark for HE qualifications. The UK cannot be perceived as offering something less. That means increasing the period of study from the start of first degree to completion of PhD from the current 6 or (more commonly) 7+ years to 8 years. This extended period is much needed also because of changes in standards at undergraduate entry and the increasing breadth required of successful PhDs.

For the 8-year approach to work, three things are vital. First, it must be implemented with sufficient flexibility to retain the advantages of the wide variety of degrees that we currently have at each level. Second, there must be an effective strategy at national level for funding the additional year or years. Third, the intermediate steps must meet the needs of the large majority of students who leave HE after an undergraduate or masters degree without proceeding to the doctorate.

Our detailed analysis of the statistics confirms a decline in numbers of UK students taking core science and engineering subjects at postgraduate levels. In order to avoid serious shortages of these vital skills, we urge both individual universities and central Government to encourage study in core STEM subjects at all levels, for example by the introduction of bursaries or reduced fees for students undertaking these courses and by promoting wider awareness of the career options that such courses open up.

Introduction

The Higher Education (HE) system is the engine of the UK's efforts to generate, store and transmit knowledge. We see today that knowledge underpins all aspects of our national well-being. A healthy HE system is now a prerequisite for a healthy society. If we are to do well in the future, we must ensure that our HE system is fit and competitive in the more challenging circumstances that we will undoubtedly face then. So this report looks forward ten years and examines some of the steps we need to take now to secure the long-term fitness of our HE system.

This is the second of two reports on the future of higher education. Our first report, *A degree of concern?*, was published in 2006. It provided a detailed statistical analysis over a ten-year timeframe of what had been happening at first degree level. We documented outputs, highlighted the importance of putting UK developments in a European and global context, and stressed the need for flexibility and breadth throughout the HE system. We emphasised the need to see the formal HE process as a start to lifelong learning, equipping graduates with the skills to adapt and flourish in changing circumstances.

In this second report the focus is on postgraduates. We concentrate on the teaching and research training functions of universities – the education of those who will use the skills, knowledge and experience gained in both their working lives and their personal lives. We describe recent trends in numbers and course structures, engagement with employers' needs, and the significance of the increasing international dimension in UK HE. We examine where the HE system needs to be in ten years time, and identify important implications for current policy.

Recent trends in postgraduate subject choices

The most immediately striking finding from our detailed statistical analysis is the impressive rate of growth over the past ten years in the number of stand-alone masters degrees[1] and doctorates awarded to students of any nationality: up by 133% (to 103,500) and 79% (to 16,000), respectively, between 1994/95 and 2004/05. The corresponding rate of growth for first degrees over this period is just 29%. For UK students only, the growth rates are more modest but still strong: 65% for masters degrees and 63% for doctorates (compared with 23% for first degrees). More and more UK students are staying on to further their studies, or are returning after a spell away from university. The traditional 3-year undergraduate degree is less and less a direct route to employment.

Of masters degrees taken by UK-domiciled students, the proportion in science subjects broadly interpreted has been constant over the past ten years at about 30% of the total. Science has thus generally held its own in the expansion of the masters sector. Within that, there has been spectacular growth in the biological sciences category (driven mainly by psychology, microbiology and sports science) and in subjects allied to medicine. The physical and mathematical sciences categories have grown at slightly below-average rates, and both chemistry and physics themselves have declined significantly. The engineering and technology category has been static, thus shrinking from 9.3% to 5.7% of the total.

At doctorate level, science has not held its own so well, dropping from 65% to 57% of degrees awarded to UK students. The disciplinary pattern is similar to that of masters degrees, with relative as well as absolute growth in biological sciences and subjects allied to medicine, some relative decline in mathematical and physical sciences, and engineering and technology again virtually static in absolute terms.

There is reason, then, to be concerned about the falling popularity of courses in some core sciences and in engineering and technology. Moreover, it would be rash to argue that even holding market share in comparison with ten years ago was enough. The future is going to need a more highly scientifically trained workforce. So we urge both individual universities and central Government to encourage study in core science subjects at all levels, for example by the introduction of bursaries or reduced fees for students undertaking these courses and by promoting wider awareness of the career options that such courses open up. The core subjects provide the essential foundation for later developments.

The financial and other hurdles associated with providing STEM courses have been extensively aired, as have the dangers of parts of the country being bereft of such courses and students unable to travel far thus being unable to study significant aspects of science. This could in turn have a significant impact on numbers of graduates staying on to take PGCE courses in STEM subjects, thus creating further pressures on STEM at school level within the region. We therefore welcome initiatives already being taken by individual institutions to collaborate regionally in the provision of key courses, and urge both institutions and Government to adopt an imaginative approach to facilitating such collaborations.

Proposed changes in course structure

For students considering a career where a PhD is relevant, we strongly support the Bologna vision of an 8-year span from starting as an undergraduate to completing the PhD. There are several cogent reasons for this.

- Where Bologna sets the benchmark, students with only 6 or 7 years of university work behind them are likely to be disadvantaged in seeking postdoctoral positions.
- If shorter courses thus become less portable in the international market, it will become more difficult to attract overseas students to the UK.
- Changes in the background knowledge of students at entry to undergraduate courses mean that it can take them longer to reach the required standard.
- A longer masters phase can provide a very effective way of providing multidisciplinary skills and experience.
- A longer first degree or masters phase can also provide opportunity to carry out original research, either in anticipation of embarking on a PhD or to develop skills useful in other career trajectories.

There are several possible approaches to structuring the proposed 8 years. For example, the mainstream Bologna approach is 3:2:3, with a 3-year first degree followed by a 2-year masters and a 3-year doctorate. A 4:1:3 approach would retain the advantages of the 4-year integrated masters that is rapidly gaining ground within STEM subjects. It could also allow for broader first years and conversion courses for those with A levels not immediately suited to their desired degree subjects. The 1-year masters would then allow an element of specialisation as a prelude either to a PhD or to employment. A 4:4 approach would combine the integrated masters with a longer doctorate that could include a larger taught component or allow extra time for writing up. In advocating the 8-year cycle we strongly stress:

- the need for flexibility in the exact structure of the 8 years, so as to suit the circumstances of individual students, institutions and disciplines – the emphasis must be on the quality of the education provided and not just its duration;

[1] This does not include 4-year courses like the MMath or MPhys, which are classified as first degrees.

- the prerequisite of effective funding mechanisms to cover the full 8 years, including both the costs incurred by the institution and the costs incurred by the student; and

- the importance of ensuring that the structure also meets the needs of those who will leave before the final, doctorate, stage.

It will be important to monitor the impact of changes in course structure on demand from both UK and non-UK students.

The employer perspective

In recent years a tremendous emphasis has been placed on knowledge transfer between universities and businesses and on commercialising research. A matching emphasis needs to be placed on a collaborative approach to learning provision that ensures that businesses and other employers are engaged in curriculum development, course design and delivery.

While attempts to quantify future labour demands are unlikely to be fruitful, there would be value in carrying out a large-scale qualitative study of the changing demands of employers. This would enable us to understand what skills, knowledge and experience they seek in the STEM graduates they employ and how that is changing. What is already clear is that employers are increasingly working with the HE sector, for example by taking on students for practical experience and by sponsoring actual or potential employees through courses.

Postgraduate education and training designed or sponsored by employers meets a very real need and should be viewed as an integral part of the educational framework. These programmes offer benefits to all three parties involved: students, employers and universities. We recommend that any future official review of STEM HE should examine such education and training to help ensure its continuation. We believe there should be more emphasis on a collaborative approach to learning between universities and industrial researchers, matching the emphasis that has been placed on knowledge transfer and commercialisation of research.

The international dimension: non-UK domiciled students studying in the UK

In proportional terms, the strongest driver for the growth in postgraduate degrees awarded is the influx into the UK of students from other parts of the EU and from outside the EU. By 2004/05 students from outside the UK accounted for 52% of all masters degrees awarded (up from 32% in 1994/95), and 39% of all doctorates (up from 33% in 1994/95). The proportion of all first degrees awarded to non-UK students, by contrast, was 11.8% in 2004/05 (up from 7.5% in 1994/95). At masters level, the rate of growth has been even stronger for non-EU students (from 9,200 to 40,400) than for other-EU students (from 5,100 to 13,600); at doctorate level it is the other-EU cohort that has grown most dramatically (from 600 to 2,100).

The subject choices of the non-UK students differ from those of UK students, though they show similar trends. Engineering and technology, and computer science, are particularly popular. The non-UK students make a major contribution to higher education in the UK. Their financial contribution is obvious, both to the university and to the locality, and it is likely that in many instances they make a crucial difference to the viability of their courses. They also enrich the cultural experience of their colleagues. The fact that so many come to the UK for part of their education must serve to strengthen the UK's influence around the world. Those who work in research, especially those remaining in the UK for postdoctoral work, constitute an important element of the UK's total research effort.

One key policy issue is the extent to which the rapid growth of non-UK students in the past ten years can be sustained in the face of the increasing global competition for talent. The quality of the experience offered to the non-UK students – many of them paying high fees – will be a major factor. Both individual institutions and policy-makers at national level must review the extent to which the HE system currently depends on its non-UK students. They need to develop strategies both for maintaining the inflow and for adapting to the eventuality of the inflow slowing down. To inform strategy at the national level it will be important to collect clear data on what non-UK students do in the years after completion of their formal studies.

Vision for the next decade

In ten years time, even more than now, the HE system needs to deliver in a context where there is increasing global competition for the best students, where we need a higher level of skill throughout the workforce, where the growing complexity of the employment market demands a corresponding diversity and flexibility in our approach to education, and where we will need a more scientifically literate citizenry. This has to be accomplished by a set of independent institutions supported by a mix of public and private funding. While we have made major investments in our HE system in the past ten years, many competitor countries have been investing even more rapidly in their own HE systems. The stakes get higher with each passing year.

And so do the opportunities. There are many signs of a population eager for knowledge. Increasing numbers at all levels of HE, particularly the increasing numbers engaging at the postgraduate stages, point to the possibility of continued expansion. We have to ensure that a sufficient proportion of these numbers is attracted into science.

The key is flexibility and a willingness to experiment. In order to flourish in the circumstances prevailing in ten years time, the HE system needs now to find ways of developing several trends already in evidence. In particular, universities and Government need to:

- encourage more students into HE and into science courses and work to impart the general scientific aptitudes that will be most useful in subsequent careers;
- develop the eight-year model for those intending to pursue careers in science, and ensure that it is properly funded so that neither universities nor potential students are discouraged;
- work more closely and imaginatively with employers at all stages of planning and delivering learning opportunities;
- recognise the range of benefits that non-UK students can provide and take steps to ensure that the UK remains effective in the international competition for mobile talent.

Higher education must remain a high political priority with strong, visible Government support. The UK has to go on demonstrating that it is really committed not just to maintaining but to improving its track record. HE is globally recognised as something in which the UK excels. We must work energetically and imaginatively to ensure that we remain at the forefront internationally if the UK is to do well in the coming decade.

1 Introduction

1.1 Challenges and opportunities

It has become a truism that science and technology are vital to our success as a nation. It is one that we have to take seriously. We need a workforce skilled in STEM to allow us to continue flourishing in an increasingly competitive world where many other nations are investing heavily in their knowledge-intensive industries. We equally need a citizenry able to handle difficult decisions about complex issues that have a strong scientific component. Both these requirements demand a vigorous Higher Education system. Put simply, the HE system underpins the UK's ability to do well.

Global competition extends to HE. Even at undergraduate level, and much more at postgraduate level, students are mobile, willing to travel internationally to find courses best suited to their needs. Academic staff have long been mobile. Where the star performers can have quite disproportionate impact, there is fierce competition for the top talent. The UK of course has the huge advantage of operating in the international language of science. But other countries, too, speak English. We have to do more than that to compete internationally.

Indeed, we have to compete not just within our traditional peer group (eg the current members of the OECD) but also with the rapidly developing economies that are increasingly marketing themselves not just on price but on the quality of their products and their workforces. Such countries are investing impressive amounts in education and training. That sets the pace for countries like the UK.

The US National Academies recently published a report that referred to this challenge as 'the gathering storm' (NAS 2005). They proposed 20 specific actions that the USA should carry out in order to retain its position as a global leader in science and technology. The four main areas of recommendation in the report are:

- increasing the supply of science teachers;
- increasing federal research funding;
- increasing the supply of science graduates and PhDs; and
- increasing innovation.

It is equally a major challenge for UK HE to generate a sufficient supply of high-quality STEM graduates not just for research and related careers (including teaching) but also for the many other sectors of employment where the analytical and numeracy skills associated with STEM subjects are of value. We must therefore ensure that the benefits of pursuing studies in science, and the wide range of career options that such studies can open up, are widely known both throughout the UK HE sector and beyond.

A further primary purpose of STEM higher education is to develop a scientifically literate society that understands the threats, challenges and opportunities facing the UK in the 21st century. Many of the major challenges facing the world will require the public to be able to make scientifically informed decisions. The UK HE system can play a vital role in producing a nation that is at ease with science, and that is able to make informed and rational decisions on scientific matters.

The Government has acknowledged the challenges the UK faces. The Leitch Review of Skills (HM Treasury 2006b) stresses that the UK cannot be complacent with our current skills levels, and that while we cannot predict future economic conditions with certainty, we do know that the demand for skills will inevitably grow. The report states that 'over one quarter of adults hold a degree, but this is less than many of our key comparators, who also invest more. Our skills base compares poorly and, critically, all of our comparators are improving. Being world class is a moving target' (p. 2). Leitch's recommendations therefore focus on increasing the skills level of the UK population, with particular emphasis on increasing intermediate and technical skills.

Government and Parliament are also considering the increasing internationalisation of the UK HE sector. The House of Commons Education & Skills Committee report on *The future sustainability of the higher education sector: international aspects* (House of Commons 2007) considers the various ways in which the UK can capitalise on this situation. Issues covered include: UK postgraduate education attracting non-UK students; UK students travelling abroad; and collaboration and partnership opportunities between the UK HE sector and its non-UK counterparts.

The UK HE sector itself is fully aware of the urgency. Universities UK's current project on the future of the HE sector in 2020 sets out to inform the UK HE sector how it can best address, and capitalise upon, these challenges to our competitive position (Universities UK 2007a).

There are also several European-level initiatives that have implications for the UK HE sector. The Bologna Process is one of these, and is considered in Chapter 4. Other initiatives include the creation of the European Research Area (ERA), which aims to facilitate and promote research throughout Europe. One aspect of the ERA has been the recent establishment of the autonomous European Research Council, which will support and fund basic research carried out by individual teams competing at European level. Additionally, there are plans to create a European Institute of Technology, which will focus on innovation, with the overall aim to reinforce Europe's capacity to transform education and research results into business opportunities.

1.2 This report

This report follows *A degree of concern?,* which we published in October 2006 and which focused on the undergraduate level (Royal Society 2006a). Both reports are strongly underpinned by a major reworking of national statistical data to provide a consistent ten-year time series in which perturbations related to, for example, changes in definitions have been removed and the real trends become apparent. This reworking was commissioned from the Higher Education Statistics Agency (HESA), and we are most grateful to HESA for its assistance with this complex task.

The analysis in this present report builds on our earlier work and focuses more on the postgraduate level, in particular on masters and doctoral study. It deals with the supply of and demand for STEM-skilled individuals in the UK, and considers whether the UK is producing both the quantity and quality of STEM-skilled graduates necessary to meet demand and to maintain the UK's position as a world-leading economy. Chapter 2 outlines the current situation of higher education in the UK, with some sense of what a world-class UK higher education sector would look like in ten years time. Chapters 3 to 6 contain analyses of: the supply of, and demand for, STEM graduates; the structure and content of STEM degrees; the involvement of employers in the provision of university education; and the increasingly international make-up of the UK student body. Recommendations appear throughout Chapters 3 to 6: these are made with the overarching goal of a world class UK HE system in 2015 and beyond firmly in mind. Chapter 7, 'Conclusions and recommendations', then contains a synthesis of the recommendations, and explores their implications.

This report and its recommendations are aimed at a variety of audiences: primarily central Government policy makers, and also HE managers, academics, and employers & industry. It is based in part on responses to a call for evidence[2]. It has been prepared by a working group chaired by Professor Judith Howard FRS[3] and has been endorsed by the Council of the Royal Society.

[2] We are grateful to those organisations that responded. They are listed in Annex 2, and their evidence is available on the Royal Society website.
[3] The full membership of the working group is given in Annex 1.

2 UK HE now and in the future

2.1 Introduction

The overarching aim of this study is to consider what needs to be done to ensure that UK HE is fit for purpose in ten years' time. We start with a description of some of the key characteristics of the current HE system and how things might change over the next decade.

Many aspects of the HE system within the UK are world class and, at present, these help the system as a whole to punch above its weight – and it is consistently ranked number two in the world behind the US. UK universities feature highly in the top ranks of many league tables and worldwide rankings. The two main international league tables covering both teaching and research functions of the university are Shanghai's Jiao Tong University's annual worldwide review, which uses relatively few criteria including Nobel prize winners among faculty and alumni, and that produced by the Times Higher Education Supplement (THES 2007) using a wider and less exclusive set of criteria and a measure of peer review. The 2006 version of the Jiao Tong review (Jiao Tong University 2006) placed five of the UK universities in the top 50, whereas the 2007 THES table included eight UK universities in its top 50 universities. Additionally the THES compiled a list of the top universities, as reviewed by employers, which places five UK universities in the top ten on this measure.

The UK and its universities are a destination of choice for both students and university staff. Increasing numbers of non-UK students undertake their HE study in the UK. Many non-UK academic staff also choose to come to UK universities, in order to take advantage of the opportunities the UK is able to offer. Within the UK itself, there is increasing demand for HE provision from prospective students. The number of UK-domiciled students undertaking first degrees has risen markedly in recent years, as has the number of students undertaking postgraduate courses such as masters.

A major strength of UK universities is their diversity and autonomy. The breadth and variety of UK universities gives potential students a wide range of choice of institutions, courses, and modes of study. This variety has also helped encourage an excellent and vibrant research base, which covers a wide range of subjects. The autonomy of UK universities is an important factor in their success. UK universities are able to act independently and to set their own priorities and areas for research on which they wish to concentrate. Some UK universities excel at research, others excel at teaching, and others excel in both areas. We fully support this diversity and believe that excellence in both research and teaching should be fully recognised and rewarded.

However, the UK HE sector's strong position is by no means set in stone, and change and instability are inevitable. While the UK is currently recognised as a world-class provider of higher education, there now exists a worldwide market in HE. The UK must compete with other providers of HE throughout the world in order to maintain its strong position. Indeed, there are some trends that already cause concern. As discussed later, university funding mechanisms have provided incentives for specific individual and institutional behaviours, and the changing ratios of staff to students make a difference to the teaching methods that can be used.

2.2 Government policy and university funding

The structure and level of funding received by universities will influence their institutional strategies and the choices of the individuals who undertake research and teaching within them. Universities can undertake only those activities that are financially viable in the long term.

When Gordon Brown became Prime Minister in June 2007 he implemented a major restructuring of Government departments. Whereas previously responsibility for education lay solely within the Department for Education & Skills, it is now split between the Department of Children, Schools and Families (DCSF) and the Department for Innovation, Universities and Skills. DIUS has responsibility for the development, funding and performance management of higher education and of further education (FE) and all of the work of FE colleges with the exception of pre-19 education. In a welcome move, DIUS brings HE together with the innovation and skills agenda and with research funded through the research councils, and therefore provides an important opportunity for coherent policy-making across this wide area.
The inevitable departmental separation of higher education from school education means that extra care will be needed to manage the interface between these two sectors.

2.2.1 UK funding of university research

There has been a sustained increase in the public investment in research, particularly in science: the 2004 10-year investment framework for science and innovation, and subsequent documents, set out a commitment to research funding. By 2007–08 the Science Budget will rise to £3.4 billion by 2007–08, more than double the level of 1997 (HM Treasury 2006a).

Research in universities is supported through the dual support mechanism. The two income streams comprise:

- funding through the research councils. This consists of grants awarded to individuals and research groups within universities for specific research projects or programmes. Research Council funds must be spent by universities on the specific research project for which the grant was awarded;

- funding from HE funding councils (HEFCE, SFC, HEFCW and DELNI), through the 'quality-related' (QR) stream, the level of which is dependent on universities' performance in the Research Assessment Exercise (RAE). Funding received through this stream is not tied to a particular research project, and can be spent at the discretion of the institution.

Much of the increase in research funding in recent years has been channelled through the research councils, without a proportionate increase in the HEFCE QR stream. The result of this is that, while universities' income from central Government funding has increased overall, they have received a smaller proportion of funding that can be spent at their own discretion. The impact of this may be that universities are less able to respond to changing priorities as they do not have sufficient funds to spend on the areas of their choice.

The next RAE takes place in 2008. Previously the RAE has consisted of a panel-based peer judgement system, but, post-2008, the RAE will move to a metrics-based assessment system for SET subjects (not including maths) (HEFCE 2007b). The implications of this change are complex, and any changes in funding will depend on the particular indicators or metrics used. The Society has called for the RAE to continue to include an element of peer review (Royal Society 2006b).

There is also a third stream of funding, which comes from other Government departments, businesses and charities, to cover contract research or to part fund collaborations.

2.2.2 UK funding of university teaching

Alongside the QR research stream, universities receive funds in the form of teaching grants from the HE funding councils. The amount of this grant currently depends on the number of students and the subjects they study. If it is not financially prudent for a university to offer a particular course of study, the university may be forced to withdraw that course, even if there was a sufficient level of student demand.

However, the method that the funding councils use to calculate teaching costs is changing, and a new framework for costing teaching based on the established principles of the transparent approach to costing (TRAC) is now being implemented. The TRAC exercise for research costs demonstrated that research costs were often unseen, and led to the payment of full economic cost of research council grants. Once completed, the TRAC exercise for teaching costs will inform the funding councils' future distribution of the funds to cover universities' teaching costs.

Additionally, in 2006, HEFCE set up a special fund to support strategically important and vulnerable subjects, which include some in the physical sciences (HEFCE 2006). HEFCE is to provide £75 million in additional funding to support very high cost science subjects, which are strategically important to the economy and society but vulnerable because of relatively low student demand. The funding over three years from 2007–08 will support chemistry; physics; mathematics; chemical engineering; and mineral, metallurgy and materials engineering – to help maintain provision in these subjects in universities and colleges while demand from students grows. The additional funding will increase the HEFCE teaching grant for these subjects by approximately 20%, or £1,000, per student. These measures should mean that teaching in STEM subjects is more fairly funded in future, and therefore that STEM departments are less likely to be seen as unviable, loss-making departments within universities, and therefore at risk of closure.

2.2.3 Universities and student fees

Since 1998, UK universities have received income from the undergraduate student fees paid by UK students. Tuition fee levels are currently capped at £3,000 per year, but this limit is due to be reviewed in 2009, when the capped amount could be raised.

Postgraduate students domiciled in the UK or other-EU countries pay fees of around £3,000 – £3,500 per year for a full-time course at most universities. Non-EU domiciled students pay considerably more – up to £15,000 per year for a full-time course. The increasing number of masters students, in particular from outside the EU, has provided universities with a valuable increased source of income. Chapter 6 contains further detail on this.

2.2.4 Looking forward: public investment in university activities

Our vision for the next decade builds on many of the characteristics of the current system. The focus is a diverse HE sector, in which independent universities draw upon their individual strengths to undertake teaching, research, community & business engagement and maintaining international links. These universities should be funded in part by Government, through mechanisms that meet the requirements of accountability but also allow institutions and researchers the freedom and authority to undertake excellent teaching and research of all kinds, on a sustainable basis. The dual support system should be retained, augmented by third stream funding from businesses and charities. Teaching must be fully funded.

Employers from the private sector and the public sector should be involved with curriculum design and course delivery at all levels, as well as research collaborations. Local consortia of businesses should provide the critical mass for student placements and for input to courses where small businesses are unable to act. Scientific industry will choose to locate R&D facilities in the UK because of the high quality and sustained volume of the workforce. In some cases there may be no local businesses working in relevant fields, in which case the involvement of national businesses and consortia would be necessary.

2.3 Government policy – the student perspective

The funding available to students, in the shape of grants, loans or bursaries, can be used to influence student choice, and therefore encourage (or discourage) the study of particular courses or subject areas. For example, the Government could encourage more students to study a subject where there is an undersupply of graduates, or encourage particular career paths through providing greater financial assistance to students who choose these options rather than other paths of study. This is already happening for teacher training courses. Manifold factors influence who attends higher education, what course they study, how they study, and what they do after attending university. Some of the major factors are considered briefly in this section.

2.3.1 Student finances

UK-domiciled undergraduate students now pay a contribution towards their tuition fees (although the situation varies between the component parts of the UK). The result of this, alongside the shift from student grants to student loans, is that many UK students graduate with sizeable debts. There are many implications arising from this changing financial situation.

- How students view themselves: students who feel they have paid a sizeable amount for their higher education will view HE more as 'consumers' than students in past did. This sense of entitlement may mean students today have different demands and expectations, which universities will need to understand and address, if they are to be deemed as offering 'value for money'.
- What course students undertake: students who pay for HE may well consider aspects of HE in more concrete financial terms than students in the past. One aspect is the financial return they can hope to receive in terms of future earnings. Some subjects bring higher returns than others, and therefore these subjects may enjoy increased demand from students. Additionally, students may have to continue to live at home during their degree course, in order to save money, and may therefore have to compromise their choice of degree if there are limited universities/courses in their geographical area.
- Student achievement: students who face high living costs and/or sizeable debts may be more likely to have to work long hours during both term time and university holidays, which could impact on their ability to achieve their full potential in their university course.
- The careers graduates pursue: students who graduate with large debts are likely to have a need/desire for higher earnings than if they had graduated with less debt. The need to pay off debts may also affect whether graduates are able to choose to continue with study, eg undertaking a masters or PhD.

2.3.2 Funding for postgraduate courses

It is also important to be aware of the funding position regarding postgraduate qualifications. Some masters students do receive funding, for example when studying a masters directly followed by a PhD (the '1+3' route). However many students who undertake masters, particularly stand-alone masters that are not directly followed by a PhD, must fund themselves. This funding situation will impact on who is able to choose to undertake postgraduate study. Also, in a context of international competition for students, it may be the case that it is sometimes easier for non-UK domiciled postgraduates to receive funding for UK-based study, than is the case for UK-domiciled postgraduates, due to the existence of funding opportunities specifically for non-UK domiciled students.

The funding available for postgraduate research students in the UK, compared with the funding available elsewhere, is also an important issue, and will affect the numbers of students who choose the UK as a destination to pursue their further study. Data collected by the office of international strategy at the University of Oxford found that in 2006 approximately 74% of DPhil students in the Mathematical, Physical and Life Sciences (MPLS) division at Oxford were fully funded. This compares with a figure of 95–100% of students receiving full funding, often guaranteed, at leading universities in the United States. (In both the UK and the US PhD funding comes from a variety of sources, including universities, research councils and other organisations) (pers comm., Heather Bell, University of Oxford).

Also, HEFCE have recently announced that students who wish to study for a qualification that is at an equivalent or lower level than the highest qualification they already possess will not receive funding. This implies that the wish to encourage lifelong learning and to create opportunities for people to gain new skills throughout their life will depend on prospective students being able to fund themselves.

2.3.3 Widening participation & increasing STEM uptake

The Government is keen to increase the percentage of people in the UK who have had some experience of higher education, and is aiming for 50% of 18- to 30-year-olds in the UK to have had some experience of HE. We support these efforts and believe that there should be no barrier to able students, regardless of socio-economic background, ethnic group or other factors, entering HE. Inevitably, the greater proportion of the UK population now entering HE has meant that a wider range of individuals are studying at UK universities than in the past. Universities are therefore having to cope with the challenges involved in teaching a more diverse student body. There have also been large increases in the number of students who pursue postgraduate study, examined further in Chapter 3.

There are several HEFCE-funded programmes aimed at helping increase uptake in key STEM subjects. These include programmes in: chemistry (Chemistry for our future – RSC); physics (Stimulating physics – IoP); mathematics (more maths grads – CMS); and engineering (London engineering project). Early indications, such as UCAS applications to STEM courses (UCAS 2007), suggest that such initiatives are beginning to make a difference to the uptake of STEM at HE level.

2.3.4 The transition from school to university

The subjects and curriculum students study at school level will have an impact on the skills and abilities of entrants to HE. Also, the subjects studied at school will affect what options are open to students when they apply to university. The career advice available within schools may also influence students' choices regarding HE. The methods of teaching and learning used in schools will have an impact on how entrants to HE deal with the university experience. School learning is increasingly syllabus-focused and exam-focused, with possible detriment to the overall educational experience in the face of narrowly conceived objectives. Entrants to HE will then need to adjust to the looser, more unstructured higher education environment, where they must develop their skills of independent learning, problem-solving, and critical thinking, amongst others. Although school education should not be viewed simply as preparation for HE, the school experience of HE entrants will inevitably influence their ability to survive and thrive within the HE environment. The fact that increasing numbers of UK school leavers are entering HE highlights the importance of ensuring that the HE sector has a voice and influence at school level.

2.3.5 Variation within the student body

There are different modes of study within HE, with recent increases in the numbers who choose part-time study (see *A degree of concern?* section 3.2.2 for more on this). However there has also been a breakdown of the full-time/part-time distinction, with increasing numbers of 'full-time' students engaged in high numbers of hours of paid work during their degree. Additionally, there have been increases in the number of individuals who enter HE later in life. These students will possess a different set of skills, ability, qualifications and expectations than an HE entrant who has just left secondary school. Older students may also have strong ties and commitments to a particular area, which will place constraints on where they can study.

2.3.6 The changing career market

To compete in today's job market students do not simply need a good university degree, but also require the softer skills, such as team working and oral/written communication skills, that are highly valued by employers. Universities have a role in imparting these skills to students, though they should also be gained through other stages and areas of life, from primary school onwards and through extra-curricular activities. In relation to STEM subjects in particular, there are also concerns that some new graduates have insufficient practical experience.

2.3.7 Looking forward: Who will be studying and why?

Students are changing, there is already no such thing as an 'average' student, and this variety we hope will continue to increase. The backgrounds, skills, abilities, attitudes to HE/career etc of HE students will vary enormously. These factors will interact in complex ways that must be fully considered by universities, Government and other relevant stakeholders.

In the next ten years, we would like to see a society made up of individuals who understand the value of learning for learning's sake, and who are ready to play an active part in a democracy that makes scientific decisions. There should be a wide choice of subjects at all levels of study, and there should be proper career information and a structure of financial incentives to ensure that the market forces of uninformed student choice are not the only factor in deciding which courses to run.

We would like to see courses in STEM subjects (indeed all subjects) accessible to all students who show themselves willing and able to be stretched in that way. We hope that school leavers will have a good understanding of the careers available following different subject choices, before the point at which the subject choices are made. We also hope that they will be encouraged to see HE as something that can be undertaken part-time alongside work, or after some years working (including working in the voluntary sector). We hope universities will collaborate with regional authorities to ensure that there is course provision across the range of subjects in all areas of the UK. We would like to see a wide variety of scholarships and bursaries available, from public, private and charitable funds, targeted at:

- the most able students;
- particularly those from less-represented socio-economic backgrounds;
- studying strategically important and currently vulnerable subjects (such as the physical sciences and mathematics);
- or courses relevant to a particular career/employment sector.

We expect careers to become more flexible, and students to be of a wider range of ages and career stages. More workplaces should link with universities to provide training, sometimes in a form equivalent to a standard HE course, sometimes in a short form, more equivalent to a diploma. Members of the highly skilled workforce in the UK should look forward to the opportunities to update their skills or to add on a new area of expertise – this training would often come linked to a workplace development opportunity. Continuous career development over a lifetime should mean that experiences in one professional field can be translated to another, with the appropriate knowledge update – possibly via a university course.

3 Are there enough STEM graduates?

3.1 Introduction

A major requirement of a higher education system is to educate sufficient numbers of students in STEM subjects, so that they are then able to play a full part in the UK workforce, and in a highly educated knowledge economy more generally.

This chapter begins with a consideration of the demand for STEM graduates. This includes a brief discussion of the key points of *A degree of concern?*, and an examination of the changing demands of employers, reflecting evidence drawn from surveys carried out by the R&D Society and the IET. There follows a consideration of the supply of STEM graduates. This includes analysis of the trends in numbers of UK students undertaking first degrees, masters and doctorates in STEM subjects. The first destinations of STEM graduates are also considered.

The section ends with a recommendation that a large-scale study be carried out in order to establish robust evidence of the skills, knowledge and experience sought by employers of STEM graduates, how this demand has changed over time, and some indication of how it might develop in the coming years. A further recommendation is that the numbers of UK-domiciled students studying STEM subjects at first degree, masters and doctoral level should continue to be monitored.

It is important, however, not to lose sight of the wider benefits and purposes of studying science (and other subjects) at higher education level. While this chapter considers HE in largely economic terms, ie producing enough graduates skilled in particular areas to meet the needs of the economy, this is obviously only a partial view of the wider purposes of higher education, and of education more generally. Students study science for several reasons – for interest, enjoyment, and so on – career prospects are only one factor among many. A focus on the needs of the economy within this chapter must not detract from the fact that the study of science for purely intellectual reasons is perfectly legitimate.

3.2 Demand for STEM graduates

In *A degree of concern?* we stated that it is difficult to estimate numbers of researchers, professional scientists, technologists, engineers, mathematicians, etc needed overall, and that it is even more difficult to estimate the numbers needed in specific disciplines. However, for the UK to compete as a major knowledge-based economy we believe the UK HE sector must comprise:

- an excellent and vibrant university research base, with a wide spread of subjects;
- a sustained supply of STEM professionals, including school and college teachers, university faculty, researchers and technicians, with appropriate skills, knowledge and experience; and
- a good mix of discipline backgrounds, crucially including science and engineering, within the general graduate workforce. There will also be a need for individuals with interdisciplinary skills.

The constantly changing nature of the workplace means that it is not necessary for UK higher education institutions (HEIs) to produce specific numbers of graduates in each STEM area, as there is often a good deal of movement between specialisms over the course of a person's working life. Also, workers should be able continually to expand and update their skills and qualifications, through lifelong learning in the shape of employer-sponsored education and training. To a significant extent therefore, a key requirement is for a HE system that produces graduates who possess strong core scientific skills, and who are able to adapt and be flexible over the course of their working lives.

Any review of employer demand for STEM graduates must take account of quality as well as quantity issues. Additionally, a consideration of the skills, attributes and qualifications needed in STEM industries, and in the UK economy in general, must address the entire workforce, rather than focus solely on graduates.

In his review of Business-University interactions, Lambert (HM Treasury 2003) makes the following observation:

'Companies in general are broadly satisfied with the quality of the graduates they recruit.

However, there are some concerns:

- *There is a mismatch between the needs of industry and the courses put on by universities in particular areas.*
- *Some businesses find it difficult to enter into a strategic dialogue about their current and future skill requirements, because there is no mechanism for them to engage with the university sector as a whole.*
- *Most businesses that have links with universities for course development do so on an individual basis, and although these links are often effective, they are limited to larger companies and cover particular business needs.*
- *Companies that specialise in some areas of science, engineering and technology (SET) are finding it difficult to recruit graduates of a suitable quality.'*

The Government's ten-year investment framework for science and innovation assessed future demand for STEM skills and concluded that, at the broadest level, the supply of STEM skills is likely to meet demand in the period to 2014 (HM Treasury 2004). Similar conclusions have been reached in other official documents (DfES 2006; DTI 2006) as well as in independent reviews, for example from the RAEng (RAEng 2006).

The recent Leitch report on skills (HM Treasury 2006b) provides an in-depth examination of the UK's skills base, and an analysis of future skills needs. The report considers skills at all levels, and therefore does not focus solely on graduate-level skills. The report states that 'the UK is in a strong position with a stable and growing economy ... [and while] ... we cannot predict future economic conditions with certainty ... we do know demand for skills will grow inexorably'. The UK's 'excellent' higher education system is praised as an important strength. The UK's weaknesses include the fact that one third of adults do not hold the equivalent of a basic school-leaving qualification. Also, there is a need to improve the UK's intermediate and technical skills. To become a world leader in skills, Leitch recommends a focus on 'economically valuable skills', and concludes that the State, employers and individuals will all have to invest more in skills (pp. 1 – 2).

As part of our earlier work we investigated the 'graduate premium' – the additional income accrued by graduates, when compared with non-graduates. A study by PricewaterhouseCoopers (PwC) for the Royal Society of Chemistry and Institute of Physics (PriceWaterhouseCoopers LLP 2005) compared first degree graduates in chemical sciences and physics, with those who held A-levels as their highest qualification. The study concluded that over a working life, the average graduate will earn around 23% more than his/her equivalent holding two or more A-levels; chemistry and physics graduates will earn on average over 30% more during their working lifetimes than A-level holders. This figure of 30% compares with between 13% and 16% in subjects including psychology, biological sciences, linguistics and history. These findings suggest that there remains a healthy demand for graduates, and STEM graduates in particular. (For further details of the study, see Chapter 7 of *A degree of concern?*).

We concluded in *A degree of concern?* that, at a broad level, there is a balance between supply and demand, and we continue to believe that this is the case. However, further consideration has suggested that, notwithstanding this broad balance, there are specific industries/sectors or particular subjects where the supply of adequately qualified STEM graduates/workers does not fully meet the demand, so that shortages exist.

The Research & Development Society carried out a survey of employers' current and future skill needs. *Higher Education in 2015 and beyond: will it meet our needs?* (R&D Society 2006) was submitted in response to our call for evidence, and analysed the specific requirements employers have when recruiting STEM graduates. The main findings include:

- employers want STEM graduates who have experience of the practical application of research and development by applying their skills and academic knowledge through industrial placements or practical projects;
- respondents also want graduates to have transferable skills such as teamworking and planning skills;
- employers' demands for graduates with strong written and oral communication skills are not being fully met; and
- several respondents also mentioned that they felt they currently have no clear way of communicating their needs to those who determine and design the contents of undergraduate courses, but that they would like more input into this.

The Institution of Engineering and Technology skills survey 2007 (IET 2007) found that the engineering and technology sector is facing a growing recruitment crisis, and that there is little confidence in the situation improving in the short or medium term. The annual survey of 500 companies found that, in 2007, 52% of businesses expect to face difficulties in recruiting adequate suitably qualified engineers, technicians or technologists, compared with 40% in 2006.

Strong demand for science and mathematics graduates comes from the teaching profession. However, too few of these graduates are opting to train to teach these subjects or to continue to teach them once they have obtained Qualified Teacher Status for this demand to be satisfied. The Royal Society's report *The UK's science and mathematics teaching workforce* details this problem, and examines related issues affecting the health of the UK's science and mathematics teaching community (Royal Society 2007).

There is a need for a large-scale study of the changing demands of employers, in particular to understand what skills, knowledge and experience they seek in the STEM graduates they employ. Such a study could examine whether the nature of this demand has changed over time, and whether the skills, knowledge and experience of the graduates they employ has changed, and the implications for the future.

3.3 Supply of STEM graduates

The UK's higher education system successfully enables many individuals to receive a high-quality education in STEM subjects at both first degree and postgraduate level.

These individuals are then able to fulfil several vital roles, in business, industry, academia and beyond, both in the UK and overseas. In terms of supply, ie the numbers of students qualifying in STEM subjects in the UK, there are many positive trends, with many subjects popular, well-subscribed and enjoying an upward trend in demand from students.

There are concerns about insufficient supply of STEM graduates in some industries due to the decline, relative to other subjects, in the number of students studying towards most STEM degrees; student-led demand and poor careers advice leading to wrong courses/options taken; attractions of high paid jobs elsewhere (to pay off student loans); and top students in biosciences and chemistry being 'creamed off' by the medical profession.

To some extent supply is flexible and can be met by the rising numbers of foreign graduates who want to work in the UK, and graduates who can be attracted into science jobs by the 'premium'. However, if perceived pressures continue, employers may be attracted to relocate in other countries that have a stronger supply of adequately trained STEM graduates and other professionals (see Chapter 6 for more on the international aspects of HE).

HESA is the official agency for the collection, analysis and dissemination of quantitative information about HE. From 2002/03 onwards there were major changes to the way in which students were counted and classified by subject of study. To obtain a more time-consistent dataset, the Society and the OSI jointly commissioned a revised set of data from HESA for the period 1994/95 to 2004/05. This new data series, as far as possible, removes the major discontinuities in the way in which students were counted pre- and post-2002/03, and allows continuous time-series data to be constructed.

Chapter 5 in *A degree of concern?* contains analysis of the data in relation to first degrees. The analysis in this section therefore focuses predominately on postgraduate qualifications – namely masters and doctorates. The masters category used throughout this chapter comprises stand-alone masters qualifications, and includes both taught masters and research masters. Integrated masters are not included in the masters category: instead, they are included in the category of first degrees, as covered in the *A degree of concern?* report.

A further point relating to the supply of science students is the finding of a report from the National Audit Office (2007) that comments on the higher than average drop-out rates of undergraduate students from STEM related courses. However, the situation is complicated, and there are some significant differences between universities and between part-time and full-time students.

Single-discipline courses provide an HE experience that enables graduates to pursue successful careers outside their discipline, some because of the skills acquired in mathematics or problem solving, and others based on more general attributes. There is a third category of career however, that falls somewhere in between – one that requires more than generic skills, but is not discipline-specific. Science policy or science journalism are examples of such careers, and opportunities within this category, especially within science policy, appear to be increasing in frequency and popularity. As argued in *A degree of concern?*, this variety of options give flexibility to students over what career to follow after their degree, or indeed during their subsequent career and also gives a large potential pool of recruits to employers wanting graduates in a particular discipline.

3.3.1 Trends in STEM HE participation

Recent years have seen large increases in participation in HE at both undergraduate and postgraduate levels in the UK. The total number of first degrees awarded to UK-domiciled students was nearly 220,000 in 1994/95 and just over 270,000 in 2004/05 – an increase of over 20%. During this period the number of masters qualifications awarded rose from 30,060 to 49,470 (an increase of 65%), and the number of doctorates awarded rose from 5,900 to 9,640 (an increase of 63%). The following figures therefore must be considered in the context of this upward trend of increased participation in HE at all levels during the time period.

The numbers of first degree graduates in specific biological and physical science subjects were considered in *A degree of concern?*, and this information is reproduced in Table 3.1, alongside the analysis of masters and doctorates in these subject areas. In all cases, it is important to look at the detail within the wider categories of biological and physical science to gain a clear picture of the numbers of students studying particular subjects. For example the table below reveals that masters in psychology account for 56% of masters obtained in the biological sciences category in 2004/05.

Although much of the data in this chapter focuses on the postgraduate qualifications of masters and doctorates, it is vital to bear in mind that there are many different options or pathways within HE study. For instance many students will undertake a first degree, followed by employment, and not return to HE study. Others will undertake a first degree followed by masters and/or doctorate study. Individuals may also return to postgraduate study after spending several years in employment. Also, in some cases individuals may study a different subject at postgraduate level to that which they studied at first degree level.

Figures 3.1 to 3.3 show the number of UK-domiciled students who obtained first degree, masters and doctoral qualifications in selected core scientific subjects. Figure 3.1 shows that the number of first degrees obtained in

Table 3.1 First degrees, masters and doctorates obtained by UK-domiciled students, 2004/05 (HESA data)[4].

	First degrees	Masters	Doctorates
Physical sciences	**11,780**	**2,240**	**1,590**
Broadly based programmes within physical sciences	250	–	–
Chemistry	2,530	250	710
Material science	30	20	30
Physics	2,080	210	370
Forensic & archaeological science	720	270	30
Astronomy	280	30	60
Geology	1,130	230	120
Ocean sciences	200	110	20
Physical & terrestrial geographical & environmental sciences	4,050	940	200
Others in physical sciences	510	180	40
Biological sciences	**25,780**	**3,380**	**1,870**
Broadly based programmes within biological sciences	180	–	–
Biology	4,340	420	440
Botany	60	30	40
Zoology	870	40	40
Genetics	460	60	60
Microbiology	690	260	90
Sports science	5,520	290	60
Molecular biology, biophysics & biochemistry	1,610	170	320
Psychology	10,900	1,920	690
Others in biological sciences	1,150	200	150
Other STEM subjects			
Mathematics	4,120	330	180
Computer science	11,240	1,670	230
Electronic & electrical engineering	3,570	530	200
Chemical, process & energy engineering	530	170	80
Mechanical engineering	2,640	250	130
Civil engineering	1,740	440	90

physics by UK-domiciled students has remained relatively stable throughout the past ten years. The numbers of biology and mathematics degrees obtained have fluctuated more over the period, yet by the end of the decade the number of degrees obtained was similar to the start of the period. However, there has been a 35% decline in the number of chemistry graduates during this time. This is in the context of an increase of over 20% in the total number of UK-domiciled first degree students.

Figure 3.2 shows that the number of masters awarded in biology has doubled over the period, from 210 to 420. Physics numbers declined until 2001/02, and have since started to recover. Mathematics has seen an increase from 170 to 330 over the period, with this increase gaining pace in the second half of the time period.

Numbers undertaking masters in chemistry have declined during the period, from 360 in 1994/95, to 250 in 2004/05. During the time period, masters obtained by UK-domiciled students in all subjects increased by 65%. However, over the period there has been an increase in the number of students undertaking integrated masters in many STEM subjects, and so when considering the number of students achieving masters-level qualifications this must be borne in mind. Figure 9 in Annex 3 shows the number of masters awarded in these four subjects, when integrated masters are included in the analysis.

The proportion of masters degrees awarded to UK-domiciled students in science subjects has remained roughly constant over the period 1994/95 to 2004/05 at about 30% of the total. Science has thus generally held

[4] Integrated masters are classified as first degrees, and therefore appear as 'first degrees' rather than 'masters'. Note that the figures in Table 3.1 are not a cohort study: for each subject the numbers of first degrees, masters and doctorates obtained are those obtained in the year 2004/05.

Figure 3.1 First degrees obtained in science and maths subjects by UK-domiciled students, 1994/95 to 2004/05 (HESA data).

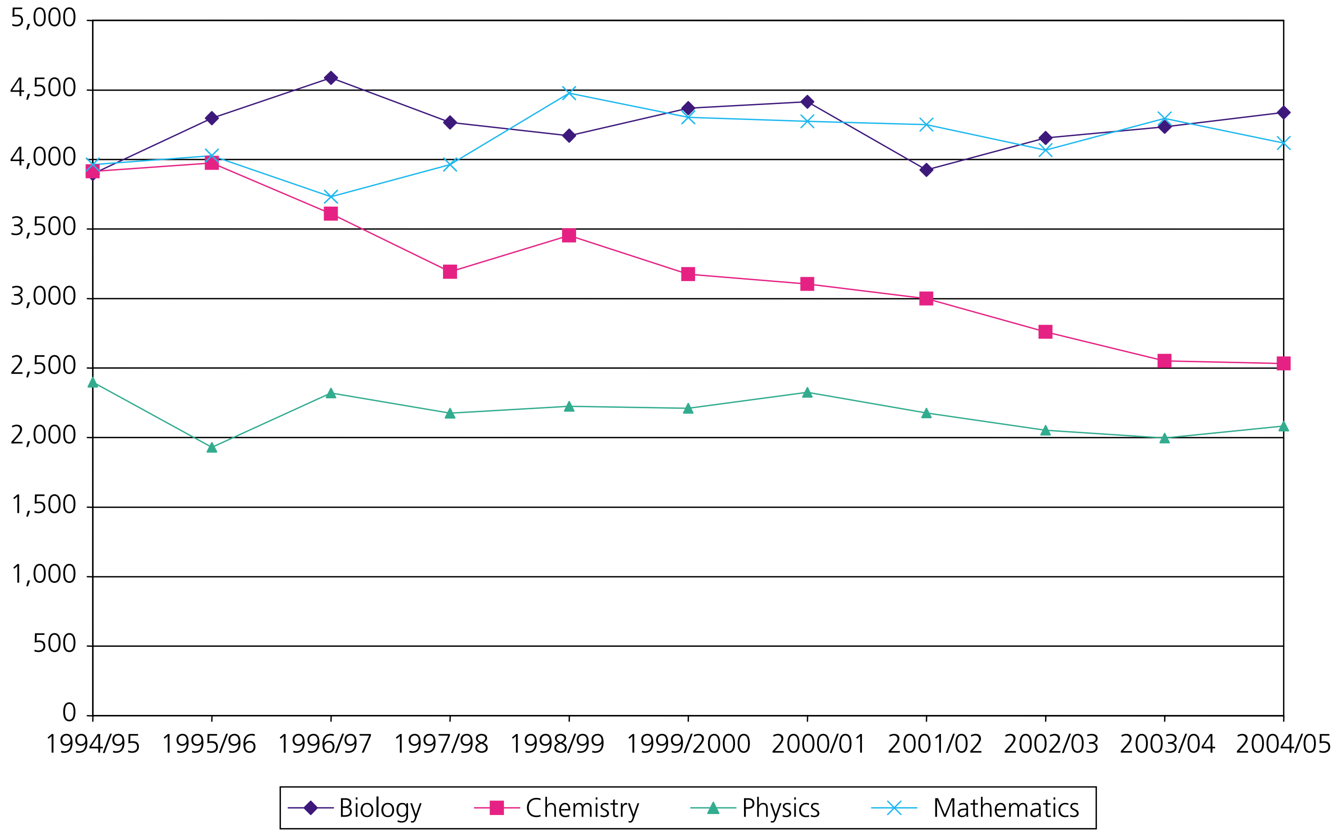


Figure 3.2 Masters degrees obtained in science and maths subjects by UK-domiciled students, 1994/95 to 2004/05 (HESA data).

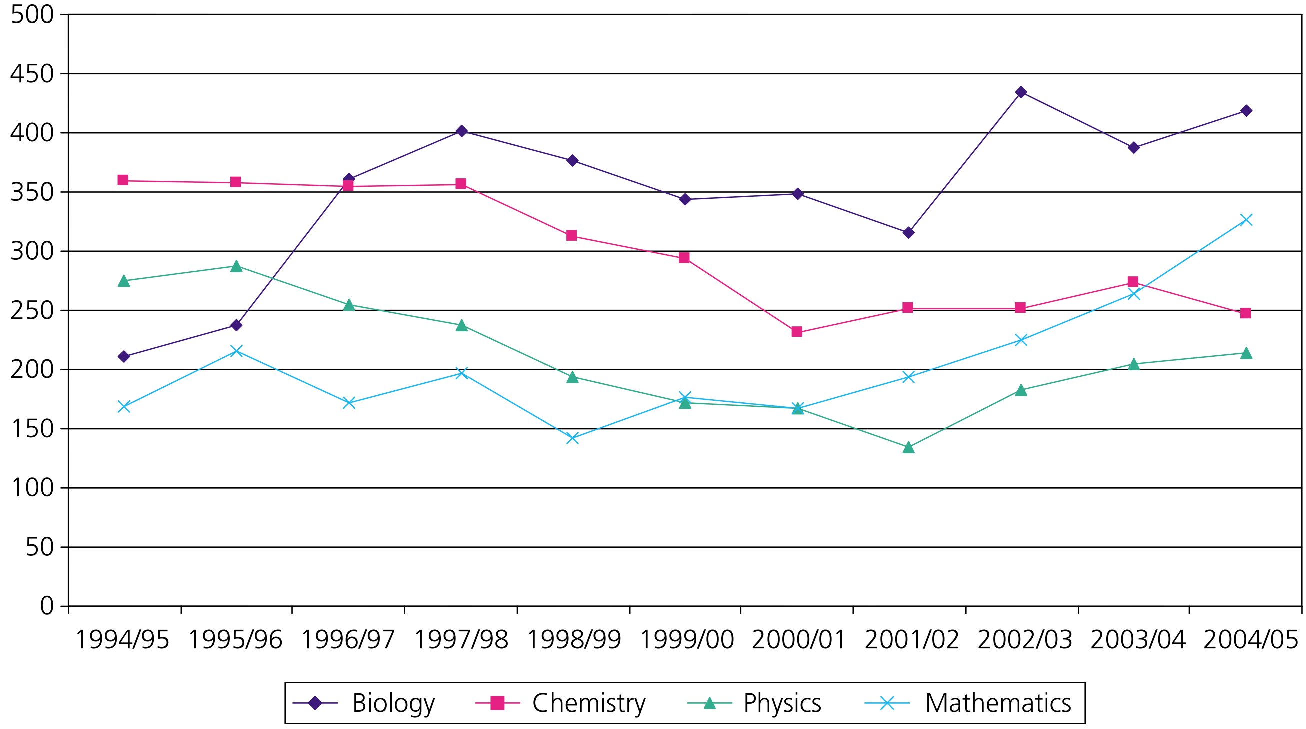
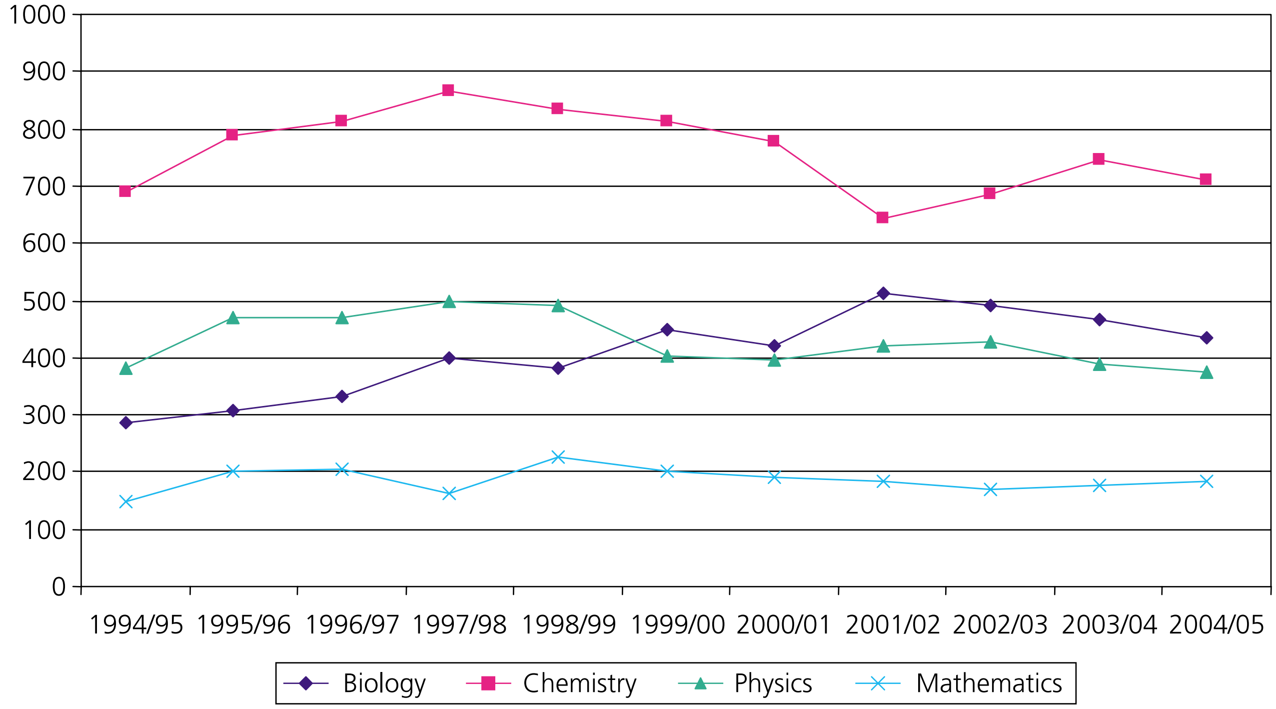


Figure 3.3 Doctorates obtained in science and maths subjects by UK-domiciled students, 1994/95 to 2004/05 (HESA data).



its own in the expansion of the masters sector. Within this, there has been strong growth in the biological sciences category (driven mainly by psychology, microbiology and sports science) and in subjects allied to medicine. The physical and mathematical sciences categories have grown at slightly below-average rates. The engineering and technology category has been static, thus shrinking from 9.3% to 5.7% of the total.

Figure 3.3 reveals that the number of doctorates awarded in maths and physics has remained relatively stable over the period. Chemistry numbers have seen more fluctuation, although by 2004/05 the number of chemistry doctorates was very similar to the number awarded in 1994/95. Biology numbers saw an overall increase of 53% over the time period. Again, this must be viewed in the context of a 63% increase in the number of doctorates in all subjects awarded to UK-domiciled students over the time period. Between 1994/95 and 2004/05 science subjects dropped from comprising 65% to 57% of doctorate degrees awarded to UK students. There was relative as well as absolute growth in biological sciences and subjects allied to medicine, some relative decline in mathematical and physical sciences, and engineering and technology again virtually static in absolute terms.

The HESA-commissioned dataset has also been used to provide detailed time series analysis of the number of masters and doctorate qualifiers in the biological sciences, the physical sciences, and engineering and computer science. See Annex 3 for this analysis. The equivalent analysis for first degrees is contained in Chapter 5 of *A degree of concern?*.

Trends in the uptake of subjects at the different levels will depend on a variety of sometimes interlinking factors. In relation to masters and doctorate qualifications, relevant factors include the following.

- The availability of postgraduate funding – from Research Councils, who fund somewhere between 13% and 16% of doctorates carried out in the UK (pers comm, Sarah Fulford EPSRC), and from other sources. Undertaking postgraduate study can be expensive, and for many students obtaining funding is essential in order to undertake a masters or doctorate.

- The changes made to undergraduate funding in recent years are likely to have an impact on the uptake of postgraduate qualifications. It may be the case that students become accustomed to taking out loans for undergraduate study, and so are more prepared to pay for postgraduate study, as they view themselves as paying customers in the higher education 'marketplace'. Alternatively, as students finish undergraduate degrees with a (sometimes sizeable) debt, they may be less willing or able to take on further debt through undertaking postgraduate study.

- The job market. If individuals cannot find a job in their preferred field, they may then choose to undertake postgraduate study. Conversely individuals may choose to enter a job if they fail to secure a place and/or funding on their preferred postgraduate course of study.

- Career entry requirements. The level to which students study various subjects will largely depend on the qualification level required to enter varying professions, for instance for some professions entrants will need to reach PhD level. There has been an increase in the total number of students undertaking postgraduate qualifications over the period. This increase could be due in part to changing requirements from employers, who are now more likely to expect a postgraduate degree as an entry requirement: standards change over time as new benchmarks become established.

- Increased participation in higher education. There has been an increase of over 20% in the number of first degrees awarded in the period 1994/95 to 2004/05. In the context of this expanding HE sector, students may be finding it increasingly desirable to obtain a postgraduate qualification in order to compete in the graduate job market. This may be especially true in the increasingly global work environment, in which graduates are competing for jobs with graduates from throughout the world.

The numbers of UK-domiciled students studying STEM subjects at first degree, masters and doctoral level should continue to be monitored. More particularly, attention must be paid to the number studying specific subjects within the broader subject areas. In the context of a likely continuing healthy demand from employers for STEM graduates any downwards trends in the number studying core science subjects must be closely monitored. Monitoring alone, however, can only be the first step. Relevant stakeholders, in particular the Government, must be prepared to take necessary action where appropriate to ensure that the supply of STEM graduates is likely to satisfy employer demand and the needs of the UK economy.

3.3.2 First destinations of postgraduate students

A degree of concern? examined the first destinations of STEM first degree qualifiers over the period 1994/95 to 2003/04. This section investigates first destinations of masters and doctorate qualifiers over the same period.

Information on the first destination of leavers from higher education is collected by HESA. Until 2001/02, the First Destinations Supplement (FDS) was used to collect information about graduate destinations. The target population included all UK and EU domiciled students reported to HESA as obtaining relevant qualifications and whose study was full-time (including sandwich students). A first destination return was not sought from part-time students. From 2002/03, the FDS was replaced by the Destinations of Leavers from Higher Education (DLHE) survey, which covers leavers from part-time as well as full-time programmes. The change from FDS to DLHE limits how meaningful any comparisons of data pre and post 2002/03 can be. A further change is the move to new Standard Occupational Classification categories in 2002/03. For this reason the analysis in this section focuses on 2003/04.

Additionally, before 2002/03, each student on a split programme was allocated to a single subject area, or to the combined subject area, as a headcount. From 2002/03 onwards, students are apportioned between the components of a split according to an apportionment algorithm (eg 50/50 for a balanced two subject programme; 66/33 for a major/minor subject split). The figures given in the subject brackets are therefore not headcounts of students, but an indication of the amount of student time devoted to various subjects.

Data for the DLHE survey is collected by higher education institutions (HEIs) following detailed guidance from HESA. A standard survey is sent by the HEI to each student identified by HESA as eligible under a standard cover letter. Online versions of the survey can be offered by the individual institutions. A follow-up letter or telephone survey may also be used by HEIs to improve their response rate; again, this must follow a standard format.

It is important to remember that the first destination statistics provide only a snapshot of destinations six months after graduation; the value of this snapshot as a longer-term indicator of destination is limited. HESA recognises the limitations of this measurement and is currently exploring the possibility of obtaining graduate data at three years after graduation. Also, this snapshot does not tell us anything about why someone has chosen to enter a particular career or whether an individual plans to spend his or her entire career in that field: it is possible that, six months after graduation, a sizeable number of graduates are employed in a stop-gap job while waiting for an employment opportunity in a particular field to arise. In time, the Futuretrack project, led by Elias and Purcell at the University of Warwick, should be able to provide us with valuable information on the transition of students into work. The project aims to provide clearer trajectories of individuals as it tracks them from the time of their UCAS application, through university, and beyond (Futuretrack 2007).

With regard to the following data it is important to note that:

- the analysis of masters graduates does not include integrated masters. Integrated masters were included in our earlier analysis of undergraduate degrees;

- some subject categories have small numbers of students, which must be borne in mind when considering the analysis;

- the number of students within each subject is shown in brackets by the subject name in each graph.

Figure 3.4 indicates the first destinations of masters students in 2003/04 in terms of employment, further study or unemployment, for a selection of STEM and non-STEM subjects. The percentage of masters graduates who enter full-time work varies between subjects. 45% of physics graduates entered full-time work, compared with 65% of engineering & technology students. There are also large variations between subjects regarding the percentage of students who continue with further study. In 2003/04 over 30% of graduates in chemistry and physics entered further study, compared with 10–15% in computer science and engineering & technology.

The first destinations of masters graduates in STEM subjects do not differ greatly from the first destinations of non-STEM graduates. In both cases a significant percentage of masters graduates undertake further study. Also, unemployment rates are not significantly different between STEM and non-STEM masters graduates.

Masters students are often self-funding: this will have implications on the choices they make following completion of their qualification. For example, graduates may need to start earning money soon after their graduation. The varying availability of doctoral funding between subjects will also have an effect on the numbers who enter further study upon completion of their masters qualification.

Figures 3.5 and 3.6 investigate the first destinations of masters and doctorate students who entered employment in 2003/04 by Standard Occupational Classification (SOC). SOC is used to classify jobs according to both the kind of work performed (job) and the competent performance of the tasks and duties (skill). Occupations are classified using indexing terms, which usually describe the job, and qualifying terms, which make the job title specific. The classification therefore depend on the level of detail provided about the job by the graduate filling in the DLHE form.

Figure 3.5 reveals that the trends appear to be quite subject-specific: there are wide variations between subjects. From this information it is difficult to ascertain how many graduates enter science-related positions. For instance we can assume those who are categorised as 'science professionals' or 'science and engineering technicians' are employed in science-related positions. However, for categories such as 'other professionals' or 'managers & senior officials' it is not possible to extrapolate this information.

With regard to doctorates, Figure 3.6 reveals that a sizeable proportion of graduates in all subject areas enter the category 'research professionals', presumably pursuing a research/academic career. Also, 20% of mathematics graduates enter jobs as 'business and statistical professionals'.

It would be interesting to compare STEM and non-STEM graduates regarding the SOC employment categories. However this is not easily achievable as the SOC categories entered by students from different subject backgrounds are so varied.

Figure 3.4 First destinations of masters graduates by subject (UK and other-EU domiciled graduates) (HESA).

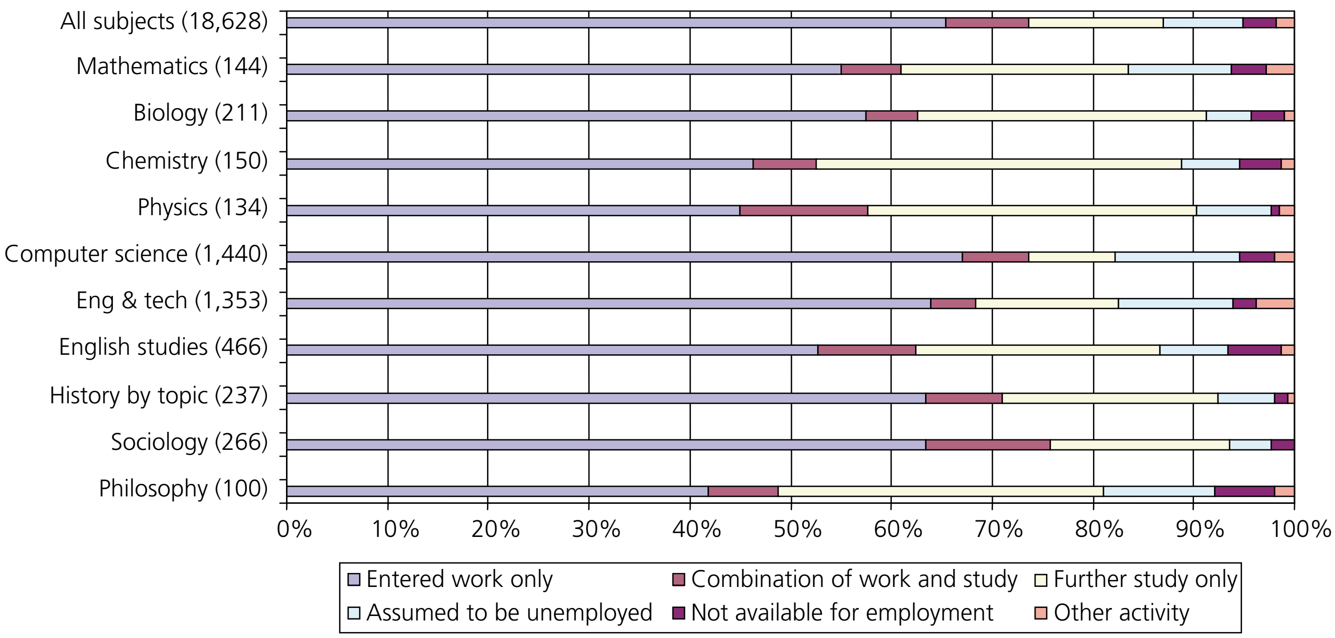


Figure 3.5 First destinations of masters graduates by Standard Occupational Classification for selected STEM subjects (UK domiciled graduates) (HESA).

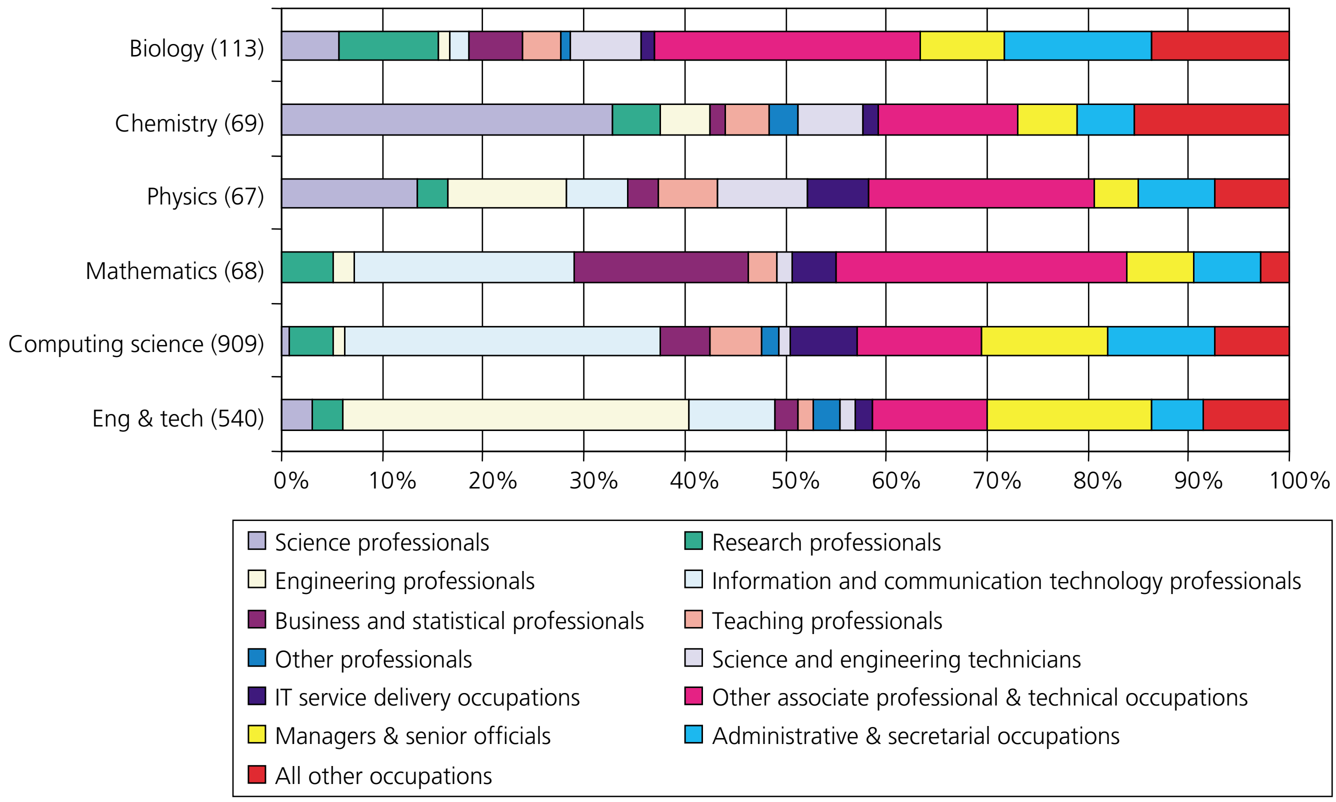
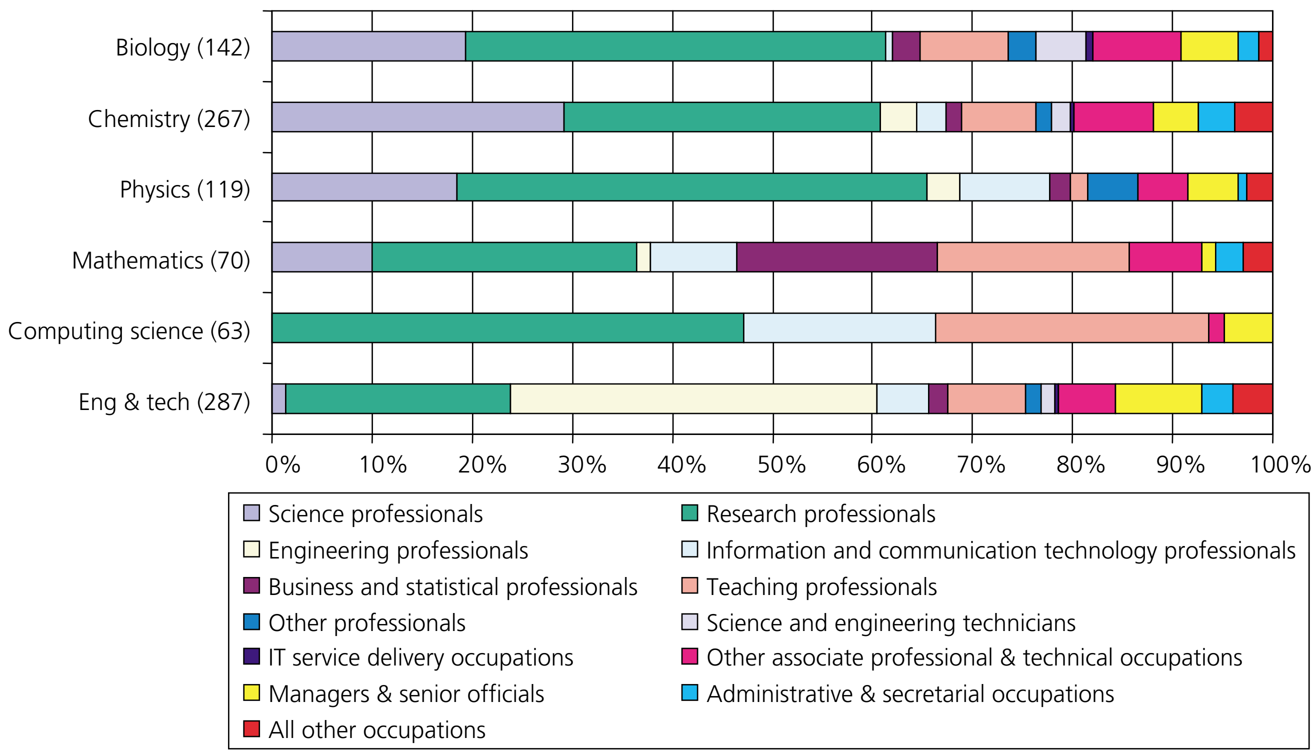


Figure 3.6 First destinations of doctorate graduates by Standard Occupational Classification for selected STEM subjects (UK domiciled graduates) (HESA).



3.4 Recommendations

- To avoid serious shortages in vital skills sets, positive action is needed by individual universities and by central Government to encourage study in core science subjects at all levels by the introduction of bursaries, reduced fees or other incentives for students undertaking these important courses.
- Specific steps must be taken by individual universities and by central Government to deliver STEM HE on a regional basis, with a priority to review areas where provision has recently changed.
- Funding should be made available for the HE sector, professional bodies, learned societies and other stakeholders to do more to advertise the benefits accruing to those with STEM skills.
- The UK Commission for Employment and Skills should undertake a detailed study of employers' needs for high-level STEM skills and knowledge and also of the extent and nature of current and likely future mismatches between supply and demand.

4 How successful are courses as preparation for further study and employment?

The previous chapter has considered the quantitative aspects of the needs of society and the economy; this chapter considers the qualitative aspects. It considers whether the courses studied are the most appropriate preparation for quality of life, wealth creation and being an active citizen. It examines the traditional routes through HE, broader course options and the overall structure of HE in the UK. It is important to bear in mind that the UK university base is extremely diverse, and that individual universities may have very different priorities or outlooks from each other.

The education and training component of HE covers the spectrum of undergraduate courses through to doctoral programmes, with some universities offering access courses, often in conjunction with further education colleges, to potential students without the standard qualifications to start an undergraduate programme. At the other end researchers continue their academic development through postdoctoral work. STEM HE courses can also fulfil wider functions, and in a general sense science courses should teach students scientific literacy and an understanding of the scientific method.

Progression through doctoral programmes is a prerequisite for senior research careers in STEM subjects, an extensive training that has also proved helpful for those who eventually pursue other careers because of the generic skills acquired such as complex modelling, pursuit of scientific enquiry and the use of underpinning technology. It is essential for the future development of the UK for this full course of HE to attract sufficient of the top students of each cohort, and their educational needs during this time, especially at the earlier stages, need to be taken fully into account in any development of the HE system.

Clearly the system needs to have suitable exit points, providing recognised qualifications for the many students who do not require the full programme at least for their first graduate job. The UK and American systems have long had bachelor and masters degrees, and indeed below bachelors degrees in the UK there have been the higher national certificates and diplomas and more recently foundation degrees. The task is to provide for the needs of all higher education students in a resource-effective way that allows everyone to reach their full potential.

4.1 Single subject degree courses and the traditional route

Single discipline courses are currently designed to take students to the frontiers of knowledge in at least part of the particular discipline, and are an important step towards subject-specific career choices such as secondary and tertiary teaching; fundamental and applied research in business and the public sector including academia; professional staff in the relevant or related disciplines in Government, public services and business (eg statisticians, medical physicists, analytical chemists); and consulting in these disciplines, based in the public and private sectors. Such courses are essential for most students wishing to progress to doctoral programmes in STEM subjects.

Most research and related professional activity within business and the public service and fundamental research institutes requires a multi-disciplinary approach. However, it also requires experts in the individual disciplines and hence is largely carried out by teams of single discipline graduates. It is necessary for each member of such a team to have confidence in the ability of the other members in their own particular discipline, as well as to be able to communicate and to work towards a common goal. Within the universities, there are also increasing opportunities for inter-disciplinary work, either in collaboration with other departments or laboratories within or outside the institution, or within specialist multi-disciplinary institutes or units.

There is a general consensus within both the academic community and the relevant employers that in most cases a single discipline first degree course is the most appropriate higher education path for professional scientists and technologists. Postgraduate courses provide the opportunity either to focus in on a specialism within the discipline, or to bring in appropriate topics from other disciplines. There also needs to be a mechanism for ensuring that students who graduate with more general degrees in the subject in question can access a professional/ specialist track. We believe a two-year masters-level course can effectively meet these demands. Additionally it is often easier to add breadth to a core skill later in life, than it is to add depth to a broader based science degree.

If supplementary disciplines can be included in the single discipline degree course, without diminishing the depth of the course, then this may provide a valuable broadening of the HE experience. However, there are problems with finding the time for such supplementary courses, and fewer are now offered. In the physical sciences and engineering, mathematics is an important component of many of the courses, although there has been some criticism that for engineering, such supplementary mathematics may be insufficiently tailored to the needs of the relevant course (RAEng 2006).

There is now a divergence in the level of degree that confers minimum entry to professional practice in a discipline in the UK. In chemistry, physics and perhaps to a lesser extent in mathematics, this minimum qualification is not yet an integrated masters or free-standing MSc degree, but it is moving that way as engineering already has done.

A first degree is also important as an entry qualification to postgraduate study. At present, it is possible to begin study for a PhD without studying for a masters first but an increasing number of universities prefer a masters as an entry qualification to a PhD. At many universities PhD students are encouraged to attend taught MSc modules.

In the biological sciences, there are very few integrated masters courses, although there is a large number of specialist freestanding masters courses. Indeed there seems to be a marked difference in structure and approach between the biological sciences on the one hand and the physical and mathematical sciences and engineering on the other. This difference may be due to fundamental differences between the life and physical sciences. It may also be due to a mixture of the more mathematical underpinning and greater additive nature of mathematics and the physical sciences compared with the situation in biology. This additive nature reduces the scope for changes to the order in which topics are considered.

There is a role for postgraduate work either in providing further expertise in a sub-discipline, or in providing single discipline graduates with appropriate knowledge and skills from another discipline. This can be provided at a postgraduate diploma or certificate level, masters or PhD. There may be worthwhile lessons to be learned from the professional training provided to accountants and lawyers.

Any discussion about ideal courses must take place in the context of the diverse range of higher education courses that exist in the UK. At postgraduate level the 1+3 doctorate, the MRes, and the MPhil are examples of the variety of courses on offer. This range of course options is a strength of UK higher education, and we fully support the continuation of this diversity.

4.1.1 UK single discipline courses: course length and standards

It has been argued that the UK system has principally been able to achieve high quality single discipline first degree STEM graduates in three years because of specialisation at 16–19, which has meant that the student brought with them knowledge and skills that provided a running start to a first degree course. However, recent changes to the nature of the school science curriculum and pedagogy (if not assessment), an increased range of options at 16, and a drive to widen participation in higher education, have led to a more diverse first degree intake with a broader range of knowledge and skills. In particular, many more students will now retain breadth in their studies at A level, perhaps choosing to mix sciences, mathematics and humanities in combinations that optimise their UCAS scores and in the often erroneous assumption that their options at university are thereby increased. All this means that UK students are likely to start their course from a less specialised base than twenty years ago, and are less likely to have been equally exposed to a wide range of laboratory- or field-based practical skills in biology, chemistry and physics at advanced level. At the same time, the disciplines themselves are expanding, with continual pressure to increase the first degree syllabus.

Coupled with this, the attitude of many students and teachers in schools is much more test-focused: teachers are increasingly assessed on how well their students do in examinations, and students are trained to learn the information they will need for their examinations. In particular, this situation restricts activities that engage students in open-ended investigation and/or allow them to pursue a particular interest, as such activities are more difficult to assess under the current system. Universities need to be able to change attitudes of incoming students to promote and encourage private study, problem solving and laboratory work.

A further difficulty is that the intake to single disciplinary courses now has a greater range of background knowledge than before. This is difficult for institutions to handle if the best students are to be sufficiently challenged in their first year, and others not to be overwhelmed. However, the QCA lays down, for example, subject-level criteria that should provide a basic common core within A-level syllabuses (Qualifications and Curriculum Authority 2007).

There are some well documented accounts of changes in the mathematical performance of new entrants to engineering and other physical sciences courses over the past few decades (Engineering and Technology Board 2000). The ETB report states that 'there is strong evidence from diagnostic tests of a steady decline over the past decade of fluency in basic mathematical skills and of the level of mathematical preparation of students accepted onto degree courses'. Smith (2004) found that the curriculum and qualifications framework failed to meet the mathematical requirements of post-14 learners and failed to meet the needs and expectations of higher education and employers. It is less clear what effect that this has had on the overall standard of the degree. It has also been suggested that university staff teach to examinations more than before. Furthermore, it does not say anything about the current international standing of the UK degree in comparison to US or other European bachelors degrees, and how this might change.

However, although universities have a legitimate voice in the development of the AS and A2 specifications, theirs is not the only input. Once the specifications have been agreed, it is important that universities respond to the input they receive, rather than treating such catch-up to past levels as 'remedial' teaching. Such an attitude can only undermine the confidence, even aspirations, of new first year students (and put off potential students) if they find that even high A-level scores are considered an inadequate preparation for their chosen degree course.

There has always been pressure to increase the content of first degree courses. However, this does not necessarily mean that the course has to be extended in duration. The main issue is the appropriate balance between teaching the student to think and the necessary acquisition of knowledge and skills. In professional training, however, it is clearly important for those graduating with a first degree to have a sound understanding of the basic fundamentals of their subject.

4.1.2 The development of integrated masters courses

In response to the perceived attractiveness of multidisciplinary courses to prospective students, and other influences prevailing at different times (discussed below), many HEIs have offered first degree courses that provide a broader science education.

The problems with the reduction of topics and their depth in A-level syllabuses, coupled with a claimed need to include new course content, has led to the introduction of an additional year to create four-year long integrated masters courses in the physical sciences and mathematics, for which there is typically selection in the second or third year. In this development, these disciplines were following the lead taken by engineering. As noted above, very few such courses are offered in biology. The graduates from these integrated masters courses appear to be attractive to potential employers. There is however, a question as to whether this is just because they act as a filter identifying the most able graduates, which would previously have been indicated by the class of the bachelors degree.

The IoP group that developed the MPhys proposals stressed that physics graduates should have a good understanding of the basic principles of their subject, which was not being achieved within the then BSc courses. It proposed that the amount of material in the BSc should be reduced in order to focus on the basic principles, and suggested that specialised options should be severely reduced. However, the latter has not happened because of fears that it would make courses less attractive. With the reduced content of the BSc, graduates were no longer as well prepared for professional work in physics and hence the fourth year was proposed to prepare graduates aiming at becoming professional physicists.

We support the continuation of integrated masters qualifications. They fulfil an important role and therefore should remain an element of UK HE for the foreseeable future.

4.1.3 The development of '1+3' PhDs

A recent development has been the growth of '1+3' PhDs, in which a student undertakes a one-year masters course directly followed by a three-year PhD. This course structure has emerged partly due to the need for a longer time period than the traditional three-year PhD, in particular the need for some students to undertake a year of pre-PhD 'training' prior to embarking on the three year PhD period.

4.2 Capacity building for new and emerging science and technology

For the UK to be internationally competitive in emerging areas of science and technology, greater flexibility in our higher education system may be required to facilitate capacity building in new, often highly interdisciplinary, areas of science and technology.

The Royal Academy of Engineering and Academy of Medical Sciences report *Systems biology: a vision for engineering and medicine* (RAEng & AMS 2007) considered the education and training that will be required to enable the UK to compete successfully in the emerging area of systems biology. It recommended that undergraduates continue to be trained in a core discipline, but that they should be exposed to problems and interaction with peers from other disciplines. The report suggested that final year undergraduate programmes, or master degrees, in life sciences could include discipline-hopping modules in engineering, mathematics or the physical sciences and vice versa.

Synthetic biology is an example of an emerging technology that may warrant a new approach to higher education. An annual international competition for undergraduates is currently providing an innovative approach to education and inspiring students to continue in the field. The International Genetically Engineered Machines (IGEM) competition (Massachusetts Institute of Technology 2007) enables undergraduate teams to compete to design biological systems from standard parts. The teams usually consist of students from different disciplines, including engineering, life sciences, computing, chemistry, physics and mathematics. Each team is provided with the same set of standardised biological parts from a registry of standard biological parts and the teams plan, undertake and later present their own projects.

This challenge provides them with an opportunity to develop new skills, learn from the experiences of others and working in an interdisciplinary environment. It also places students at the cutting edge of research and allows students to make a valuable contribution to the research field by publishing papers and developing new standard parts. The competition started in 2004 with 4 teams and this has grown rapidly to 57 teams from Europe, North and South America, Asia and Australia in 2007.

This competition enables students to benefit from the ownership of a project from start to finish and being part of an interdisciplinary team. This can be lacking in traditional approaches to education. The UK's higher education system needs to be flexible and support new educational approaches in order to produce graduates with the right mix of interdisciplinary skills if the UK is to successfully compete in emerging areas of science and technologies.

4.3 Broader science degrees

In response to influences prevailing at different times (discussed below), many HEIs have offered first degree courses that provide a broader science education by exposing students to a wider range of subjects than traditional programmes. Because of the greater breadth of such programmes, students will necessarily study core sciences in less depth. Robbins (1964) recommended that universities develop such courses, which would have equal esteem to single discipline courses, and this point has been stressed by many subsequent reports. There has been a wide range of such courses, typically categorised as either:

- *multi-disciplinary* – courses that draw from two or more core disciplines, but without necessarily linking them in any way
- *inter-disciplinary* – courses that draw from two or more core disciplines, but where significant resources are devoted to integrating (making connections between) elements from the different sciences

At the individual course level, programmes have been given a variety of names including natural sciences, general science, liberal studies in science, integrated sciences, combined sciences and human sciences. Unfortunately, such course descriptors are not used consistently, and two programmes with the same name may differ fundamentally in content and in other ways. Descriptions of some of the models that have been delivered over the years are provided in Annex 4.

Although it is too early to form a clear view on the new Integrated Sciences degrees promoted by the Institute of Physics (see Annex 4), it is possible that this novel approach to branding, combined with the extra funding on offer, will help HEIs to devise and sustain courses for long enough to produce a stream of successful graduates. We recommend that an independent review should be carried out of Integrated Sciences degrees, after a period (of perhaps 5 years) has elapsed

We have emphasised in previous chapters that, for individuals who plan STEM careers (research, academia, etc), the depth of knowledge and understanding gained from the study of a single core discipline will normally be the best foundation at initial degree level. Indeed, even for those who do not remain in science, the analytical and problem-solving skills acquired in core discipline degree can be invaluable and marketable.

Where science proceeds by interdisciplinary work, this is often achieved very effectively by specialists working together. While there are clearly benefits to individuals having an inter-disciplinary background, in our opinion this is more appropriate to two-year masters-level study built upon the foundation of a core science degree at initial degree level. Nonetheless, broader science programmes at first degree level offer several potential benefits.

- They may appeal to many prospective students who are not attracted by traditional single-subject STEM courses.
- They may also attract those who lack the appropriate school-leaving qualifications for traditional single-subject STEM courses.
- Some graduates may be enabled by such education to move – after further training – into traditional STEM careers.
- A broader programme may be a good preparation for certain careers where a wider understanding of science is an advantage. A well-designed and delivered broader science course may be an ideal background for those planning to enter teaching, a career in science communication or journalism, or science policy.
- More generally, such a course has the potential to deliver a diverse and interesting range of learning experiences and skills, which may be a very suitable preparation for work and citizenship in the 21st century, for students who do not plan to enter science careers.
- Traditional laboratory-based courses are expensive to deliver, and the additional resources expended would be wasted on students who are definitely not interested in the practical elements. There may be less need for a broader programme to include major practical elements.

However, the evidence to date indicates that it is very difficult to devise a broader science degree that has coherence and sufficient depth to ensure parity of esteem with traditional core disciplines. This is because:

- significant resources are needed to ensure that the programme has intellectual coherence and is not simply a mish-mash of modules drawn from other programmes; and
- even when such resources are available, there may be genuine difficulty in selecting appropriate science from each discipline to create a coherent whole, and there may be a powerful countervailing tendency to choose those areas that reflect faculty interest.

Even where it is possible to launch such a programme, it may be difficult to market to prospective students and so become sustainable.

- School teachers, careers advisers and parents, prefer to steer pupils towards traditional single-subject degree courses that have clear track records in providing their graduates with a range of attractive career options. This is a difficult obstacle for any new programme to overcome.
- Employers may be sceptical about a new product, when they are familiar and happy with the traditional core science degrees. With a limited track record, and the risk of employer scepticism, it is difficult to attract students to apply for such courses.
- It is possible that such resistance is based more on prejudice than objective analysis, but such prejudice may be hard to shift when such courses come into competition with the well-established traditional science model. Indeed, if promotional material places any emphasis on a course's suitability for those planning non-science careers, this risks reinforcing prejudices against the course.
- While such courses may (as in the case of integrated sciences) offer their students a route into a core science discipline, where they lack the requisite A-level qualifications, this will usually require an extra year's HE study. This will inevitably involve extra costs and may limit the appeal of this particular feature.
- The sustainability of such a course may be heavily dependent upon the continuing commitment and dedication of its academic staff and/or external funding.

4.4 The Bologna Process and the UK

The Bologna Declaration, signed by European Ministers for Education in 1999, expressed the goal of developing a European Higher Education Area by 2010 (UK Europe Unit 2007). Through specific objectives, the Bologna Process is working towards developing a coherent European HE environment to foster employability and mobility in Europe. It also aims to increase the competitiveness of European HE in the world. The aim to harmonise the three higher education 'cycles' – undergraduate, masters and doctorate – throughout Europe is of particular interest to all those interested in the structure of HE in the future, including the Society (Royal Society 2006a, 2006c). Bologna recommends a HE system comprising a three-year undergraduate degree, a two-year masters (which must be completed before a doctorate), and a three-year doctorate. This arrangement is often denoted '3:2:3'.

A vital aspect of the effectiveness of any HE system is the structure of qualifications, including the length of time taken to complete them. The Bologna Process is a key driver in leading us to consider degree structures at this present time. However in this study we have considered HE structures more broadly, and not solely with reference to Bologna. Although the time taken to complete a qualification is not the only measure, it is relevant when considering degree structure. A consideration of the learning outcomes achieved is also essential. We believe that the Bologna Process has the potential to act as a driver for change in UK HE: the process provides an opportunity for the UK to consider whether our current system is delivering what students, employers, the economy and wider society need from its graduates.

The Bologna Process will have profound consequences for the flows of students and graduates within Europe and beyond. It is important that consideration is given to how the UK engages with the Bologna developments to maximise these opportunities for the nation. If UK qualifications are not recognised abroad, or are seen as second-rate as they do not comply with the Bologna Process, there are potential problems for both overseas recruitment to UK courses, and for the international mobility of UK students and graduates.

4.5 A UK approach to the 8-year HE cycle

More time is needed for higher education. There is a perception that UK students may be less mature and knowledgeable than their European counterparts. There are also concerns from employers that students need more knowledge, and from course tutors about the need to cover material at university that was previously taught at A-level. We propose that the most appropriate way to deal with this limitation is to increase the overall length of the training period at universities. While it is vital that there should be flexibility within the system it seems that an extra year in the university cycle (ie from the current 6 or 7+ years to 8 years) would be appropriate to achieve this goal in many cases. In some cases this would in practice mean an additional two years of training, where students undertake a three year undergraduate degree followed by a three year PhD. We therefore recommend a total cycle length of 8 years full time equivalent from entry at undergraduate level to completion of a PhD.

One way of dividing the eight years would be the 3:2:3 cycle, as proposed by the Bologna Process, comprising a three-year undergraduate degree, followed by a two-year masters, and then a three-year PhD. There are a wide variety of courses that can make up the 8 year study period. Equally valid routes include a three-year undergraduate degree followed by a one-year masters, or a four-year integrated masters (which have a major emphasis on research in the final fourth year), followed by a four-year PhD. Courses such as the four-year BSc with a foundation year, or the four-year first degree with a year spent in industry are examples of the diversity at first degree level.

At postgraduate level the 1+3 doctorate, the MRes and the MPhil, and the increasingly widespread four-year PhD are examples of the variety of courses on offer. The appropriate course breakdown will also vary between subjects – some subjects will lend themselves to particular routes, which for whatever reason are not appropriate for other subjects.

Two-year masters courses, which provide opportunities for further specialisation in a subject previously studied and/or the opportunity to broaden an individual's knowledge, will be important. Whether an extra discipline is separate (such as economics following engineering) or more linked (ethics following biology), or indeed vocationally focused (such as science journalism), this extra opportunity to develop critical thinking and to apply it to real problems will be valued by future employers and PhD supervisors.

However, the one-year masters courses currently on offer in the UK are an extremely important component of UK HE, which we believe should continue alongside two-year masters. One-year masters provide an opportunity for those individuals who are willing and able to study intensively to gain a masters qualification in a shorter timespan. UK one-year masters are also extremely popular with non-UK domiciled students, who choose to come to the UK to study for these qualifications (see Chapter 6 for more on international students).

There is a great deal of variation within the masters qualifications on offer in the UK. Two diverse examples would be the one-year highly vocational masters which may be sponsored by business, and the more research-orientated two-year MPhil or MRes degrees which can function as precursors to PhDs.

This variety of possible routes through higher education is an extremely valuable feature of the UK HE system. In implementing the Bologna vision of the 8-year envelope, it is vital that institutions retain the flexibility to offer a structure suited to their circumstances and the requirements of individual students. Individuals must be able to progress at the pace that is right for them.

The UK Government must be prepared to take action on any funding issues that arise from the lengthening of the study period to eight years, and indeed to ensure that the individual courses within the current structure are properly funded. Additional funding is essential if any changes are to be made to the length of time it takes to complete qualifications: the Government must ensure both that universities receive sufficient funding, and that students are adequately supported financially for the full duration of their course. Without this guarantee, the UK HE system would not be able to comply with extensions to course structures. The issue of financial support must be fully considered and any necessary action must be implemented before any changes to the length of any of the cycles are made. The funding available to students for the second cycle is especially important as research councils in the UK are progressively withdrawing from offering masters funding, thus leaving a funding gap between undergraduate and postgraduate study.

4.6 Recommendations

- Single subject first degree courses must be protected as a vital part of the HE experience.
- At the same time, broader courses covering a wider range of science subjects should continue to be developed, as they may prepare people to be scientifically literate citizens and they offer more progression routes for students with a range of backgrounds and aspirations.
- Formal higher education in STEM subjects should normally take the equivalent of eight years full-time study from starting a first degree to finishing doctoral study, in accordance with the Bologna Declaration. It is essential that all levels of study within the 8-year envelope are properly funded. It is also essential that institutions retain full flexibility in determining how they structure the 8 years.
- The current four-year initial degrees in the physical and mathematical sciences and engineering ('integrated masters' degrees) should be retained for the foreseeable future as an effective response to the changing intake and changes in the subject disciplines.
- When changes to school-level qualifications and courses are proposed and implemented, the needs of students entering STEM HE, particularly with respect to mathematical skills, must be explicitly taken into account.

5 Are employers engaged with universities?

5.1 Introduction

Relationships between universities and businesses take many different forms, ranging from long-term strategic partnerships (often focused on the conduct of research) to more informal interactions such as conferences and networking where the emphasis is on the diffusion of knowledge (not all of which is derived from research conducted within the university). Some examples of different types of relationships and engagements are:

- Recruitment of graduates/post docs
- Collaborative research/projects
- Contract research
- Consultancy
- Licensing arrangements
- CPD/other training courses
- Conferences/networks/publishing
- Industry input to curricula
- Secondments/placements (students and staff)
- Co-sponsored appointments
- Representation on governing/advisory structures

Successive surveys of interaction between universities and businesses indicate continued growth in levels of collaboration in key areas (HEFCE 2007a). This chapter examines a key aspect of the interface between STEM HE and the workplace: postgraduate education and training of STEM graduate employees.

There are compelling reasons for employers to work with universities. These include: rapidly changing markets, the adoption and diffusion of new technologies and practices and the pressure of competition place ever-increasing demands on businesses, including rapidly changing skills requirements. Evidence shows that firms depend primarily on workforce skills to gain a competitive advantage and improve business performance[5] (CBI 2005a). Accepting that the primary role of universities is to educate and not simply to equip students with skills for business, there is an important role for universities to play in meeting these challenges, as acknowledged by many commentators and reports (such as the Lambert and Leitch reviews, and the science and innovation investment framework).

Lord Leitch's 2006 report (HM Treasury 2006b) addressed the importance of improved skills (at all levels) in the pursuit of future economic prosperity and improved productivity. In particular, he emphasised the need for a demand-led approach to skills, calling for growth in levels of employer investment in higher level qualifications including apprenticeships, degree and postgraduate levels as well as more workplace training.

The benefits of improved skills do not only accrue at the firm level – the economic and social benefits are widespread. Michael Porter's 2003 study (DTI 2003) of the productivity gap between the UK and its main rivals described an economy in transition. Where, historically, the UK had competed successfully on the basis of low costs it must now compete on the basis of added value and innovation. Lord Leitch's work underlined the important contribution of improved skills to the achievement of greater productivity, the development of a high value economy and increased levels of innovation.

On the face of it, the Higher Education-Business and Community Interaction (HE-BCI) survey data would appear to show a healthy and burgeoning relationship between employers and universities. But in spite of these impressive indicators there remain some problems. In his 2003 report on business university collaboration, Richard Lambert said 'Companies and universities are not natural partners: their cultures and their missions are different' (HM Treasury 2003). This is reinforced by the findings of the 2005 CBI Innovation survey (CBI 2005a), which found that while collaborations with universities were on the increase employers rated their effectiveness as low. Both universities and businesses agreed that this apparent ineffectiveness was due to a lack of understanding between the two communities.

HE–BCI data for 2005–06 showed that universities earned over £400m[6] from businesses and other external sources for CPD and training – compared with less than £130m in 2002–03. But this increase belies an uncomfortable reality. The CBI estimated that the total spending in this area was £23.5bn in 2004. So while businesses are turning more and more to universities to assist with workforce development and education, there is clearly a significant market that universities could tap into.

---

[5] 'Our surveys show that employers value workforce and management skills as being the most important factors in gaining competitive advantage.'
[6] Estimated to be equivalent to more than 3.6 million days of education.

In 2003 Lambert said: 'Overall, and contrary to some suggestions, universities are doing a good job in meeting the needs of businesses for skilled graduates and postgraduates in most areas. But more needs to be done by both universities and businesses to work together to meet the continuing demands of the economy. Government also needs to ensure that the structures within which universities operate are sufficiently responsive to encourage these collaborations to occur.' Research Councils are third parties or even co-sponsors in many of these activities.

Since this time a considerable emphasis has been placed on encouraging businesses and universities to work together – developing universities' 'third stream' mission. But most of this effort has concentrated on optimising the benefits of universities' research output by engaging users and investing in knowledge transfer. In the context of the third stream, less attention has been paid to the engagement of employers in universities' other core mission of teaching and learning.

Lambert said that the challenge was to raise business demand, but for the most part he was considering research. How has demand for teaching and learning developed since 2003 and how have universities responded? He said, 'universities will have to get better at identifying their areas of competitive strength in research'. It is arguable that universities should also do more to assess their opportunities in relation to CPD and teaching in partnership with businesses.

5.2 Postgraduate education and training by employers of STEM graduates

For a long time employers have played an important role in the training and education of workers in the STEM field. This has ranged widely, from the provision of apprenticeships and in-house continuing professional development to the sponsorship of senior employees needing time away from the workplace to complete postgraduate qualifications.

The past few decades have seen a growth in the number of postgraduate level taught programmes, designed for individuals working in STEM jobs (or about to seek work there) and delivered by HEIs and supported by employers in some way.

Such arrangements may involve a substantial corporate outlay, and so cast useful light on employer attitudes towards the skills, knowledge and experience of new graduates, and their training and education requirements as they progress through their careers.

There is a wide range of such arrangements, including:

- Training for prospective employees (Box 1)
- Training for employees at an early stage in their career (Box 2)
- Education for a range of employees (Box 3)
- Training for a specialism (Box 4)
- Management education (Box 5)

Box 1 Training for prospective employees

Information Technology for e-Commerce – A collaboration between American Express (Amex) and the University of Sussex

Amex has its European headquarters in the UK. For some time it had been outsourcing its major IT applications, and had become concerned that it should be developing more local talent and bringing the work in-house. In 2003 it launched a programme that sponsors honours graduates who take up part-time places on the MSc in Information Technology for e-Commerce course offered by the University of Sussex.

On admission to the course, students enter a two-year arrangement with Amex, and are paid to work for the company 30 hours a week in parallel with approximately 20 hours devoted to course work. Amex also pays their fees. Most students devote their dissertation to 'real' Amex problems. On completion of the course, the highest performing students have the opportunity to gain full-time employment with the company, and many recent graduates have obtained employment in this way. Graduates of the programme have also begun to enjoy subsequent career progression within Amex.

Box 2 Training for employees at an early stage in their career

MSc in Actuarial Finance at Tanaka Business School, Imperial College London

Graduates seeking to qualify as actuaries usually take up a relevant employment – perhaps with a consultancy firm or insurance company – which they combine with studying towards the professional actuarial examinations of the Institute of Actuaries or the Faculty of Actuaries.

The *MSc in Actuarial Finance* is a part-time programme – launched in 2006 by the Tanaka Business School in consultation with professional firms – that aims to provide actuarial students with a comprehensive background in business finance. Those who graduate will automatically be granted certain exemptions from the professional actuarial examinations and, at the same time, gain breadth and depth of understanding beyond that required for the actuarial qualification.

Watson Wyatt Limited is one of several companies that are sponsoring students on this course. It pays their fees and allows them time off to attend the programme. The company considers that the degree will give their new employees key skills and knowledge required for a modern actuarial career and 'help us take maximum advantage of the excellent graduates that we recruit'. There are the additional benefits that the receipt of exemptions may accelerate the professional qualification process and that graduates may be attracted to work for a firm that offers this new programme.

Box 3 Education for a range of employees

The BT MSc in Information and Communication Technologies – A collaboration between BT and University College London

This programme was established over 15 years ago and caters to the needs of new graduates as well as those who have been out of education for some years or may not ever have attended university. It was recently reviewed and overhauled to align it with the 21st century network, an All Internet Protocol network being rolled out across the UK over the next few years, and networked ICT.

It is a part-time educational programme accredited by UCL and offered to employees of the company – and certain associated businesses – in the UK and Asia. Lectures are given at UCL in London and relayed simultaneously to lecture hall 'hubs' at BT's offices in Suffolk, in Mumbai and Pune in India, and in Kuala Lumpur. The lecturer can see each lecture hall on-screen, and there is facility for remote students to e-mail questions during breaks.

Students are required to complete 10 modules and a project, and this takes 2–5 years. They initially enrol as 'Associates' and must satisfactorily complete three modules before they are formally accepted onto the MSc programme. This enables students to explore whether they are willing to commit to the full course, and course administrators to determine whether they have the capabilities to complete it.

The company considers that the programme is building its intellectual capital in specific 'high value' areas (and is not simply training or continuing professional development). The company has considerable influence over the course content, with each module having a 'BT owner' within the company who ensures its business relevance and an 'academic owner' at UCL to ensure academic quality. BT and UCL are working with e-Skills UK, the Sector Skills Council for IT and Telecoms, to make the MSc modules available to other employers in the sector as part of the professional competency framework that e-Skills UK are developing.

Box 4 Training for a specialism

Many employers sponsor attendance by employees on masters-level programmes which deliver knowledge and skills in a particular specialist area in which they are working or will be working in the future.

This is often combined with a recognition that it is increasingly common for STEM workers to move between several different areas during the course of their careers, and employers may now be more concerned with the qualities of job applicants, than with their existing knowledge and qualifications at the time that they join the company. A spokesperson for Rolls-Royce has said: 'The company wants to recruit the best people with the necessary attributes, learning skills and enthusiasm to learn. Adding the knowledge is then relatively easy.' So, for example, Rolls-Royce supports a range of specialist courses at Swansea University; these are embedded in the Rolls-Royce training brochure, delivered on company property by Swansea academics – and in some cases supported by Rolls-Royce specialists. (The company also offers a range of other courses, including its Engineering Early Development Programme and courses in technical and management areas.)

Box 5 Management education

A collaboration between AstraZeneca, Syngenta, and Warwick Manufacturing Group (University of Warwick)

This is a bespoke programme comprising seven residential modules each of five days duration and a company based project, usually spread over a period of two years. Modules cover topics such as strategic decision-making, leading change and improving personal performance, operations management in lean supply chains, innovation and compliance and performance management. Delegates are existing employees in manufacturing and supply areas of the companies (who sponsor their attendance on the programme); to date, delegates based in 24 countries across the globe have graduated from the programme. Typically they will have been working for some years, and the best people are selected to attend the course, in order to broaden and improve their skills. The course is set at masters level, and hence academic credits can be transferred into WMG's MSc programmes.

5.3 Broad findings – employers and university courses

The types of courses with which employers are involved are diverse. For example:

- they may be full-time or part-time;
- they may extend over a period of a year or more, or comprise much shorter module(s);
- the learning may lead to a masters degree, diploma, certificate or no formal recognition at all;
- courses attended by employees may be exclusively available to those of a particular organisation or organisations, or open to students more generally;
- learning may be by attendance in person – at an HEI, workplace or other venue – or by electronic media;
- there is often a practical element based in the work-place, which will vary according to the sector in which the student works;
- most courses appear designed to enhance students' technical or business skills.

The nature and amount of employer sponsorship can also vary substantially. A common arrangement is for the employer to pay the fees for an employee to participate in the programme (which can vary from less than £5,000 to over £20,000 per student), but may also involve

- travel, subsistence and accommodation costs
- a grant to the HEI by employers or employer organisations
- other grants in cash or kind to the HEI
- employer involvement in hosting course arrangements
- providing lecturers and/or steering group members

Given the above variations and the absence of any formal national tracking process, it is impossible to put a figure to the number of students who undertake courses that include employer involvement of some kind. However it is clear that the level of activity is significant, involving thousands of STEM-graduate employees at any time. For example, in 2007 there were approximately 600 students registered on the BT MSc course – see box 3 above.

In part, such education and training meets the modern need for lifelong learning in a rapidly changing world. It can also meet the need – in certain professions – for workers to be educated at least to a masters level.

One further point that has become clear is that such education and training is rarely if ever set up to address deficiencies perceived by employers in the first degree education of new recruits, except perhaps the declining level of practical work and work experience in first degrees.

5.4 The benefits derived from employer involvement in university courses

These programmes appear to offer benefits to all three parties involved; students, employers and HEIs. From a student perspective, sometimes this can be the only route for an individual to obtain a masters-level education or training, as public funding is not always available for post-graduate taught programmes. In comparison to other postgraduate courses, these kinds of opportunities might also prepare students better to meet the needs of particular employers, or to begin a specific career.

From an employer's perspective such courses offer a range of benefits:

- a means to deliver the appropriate skills, knowledge and experience at the right time in an individual's career, to coincide with a business need. This may be in preparation for entry to work, a new specialism, CPD, the assumption of management responsibilities or other changes;
- a means of ensuring a stream of prospective employees – a good employee training programme

can be a 'hook' to recruit best candidates, while sponsoring the training of graduates not yet employed by the company can create or expand the pool of prospective recruits;

- because the employer has a degree of influence over course design, they may use this to bring together teaching skills or expertise from more than one HEI;
- an opportunity to better understand a university, thereby opening doors to further collaborations in research, education provision etc.

HEIs benefit from:

- the stream of work/income this activity may offer; some HEIs derive considerable income from servicing employer demand;
- the involvement of employers in determining course content, which ensures that the programme remains relevant and up-to-date and therefore more attractive to students who have an eye on employment prospects;
- the possible development of new relationships in other areas such as research or consultancy and the opportunity to attract other employers to engage with that HEI – in short, an increased profile among the student and business markets;
- the opportunity for keeping academic teachers appraised of the activities being undertaken by firms, which may benefit their development of undergraduate and other courses.

5.5 Practical issues regarding employer involvement

Employer influence – The level of influence the employer may expect to exert on curriculum content will depend upon the level of the sponsorship. For example, if a closed course is under discussion which will be attended solely by a stream of employees from one organisation, then the employer may want considerable influence. Where the employer is one of a consortium supporting a particular programme, then their individual influence will be less.

Responding to business needs – Where business and HEIs work together on postgraduate education or training, the HEI needs to be flexible in response to business needs – eg timing of lectures, offering a menu of different qualifications or modules, being prepared to accredit or approve courses/curriculum changes more quickly than is customary, finding flexible ways of course delivery (eg by electronic means).

Small and medium-sized enterprises – SMEs may lack resources to fund postgraduate education and training, but can benefit where several firms work together. Such collaboration may be facilitated by a local HEI setting up a course, or firms collaborating at a local level to offer practical opportunities for graduates.

Employees of HEIs – There is an increasing number of employees of HEIs – perhaps laboratory technicians – who are also studying towards degrees and may receive some support towards this from the employing institution. This may have implications for their status as students if they are also employed by the university.

Gateways – Employers and HEIs may be missing opportunities for collaboration because prospective partners cannot find a gateway into their organisation. This provides an opportunity for other bodies to act as brokers or suppliers – eg RSC 4 Business series. HE-BCI data shows increasing numbers of dedicated staff/entry points for businesses, principally SMEs, across all HEIs. Their focus, however, may be on generating research, consultancy and licensing income. While we acknowledge this increase in staffing, such offices should not overlook the importance of reaching out to employers on the education/training front. It is also the case that many employers overlook or do not think of universities as suppliers of skills, even at this kind of level. A more concerted effort from HEIs to reach out and meet demand might be warranted.

Risks and sustainability – A key consideration in designing any course is whether it will be sustainable. Arrangements focused on meeting a short-term training need may become unsustainable in the longer term. More generally, programmes can be subject to cuts in response to changes in the business environment. Sometimes it is possible to hedge against such risks by setting up a programme as a consortium of employers, or by building in plans to include employees of other organisations over a period of time. CPD and training budgets can be vulnerable when economic conditions/trading is difficult – it is often said that they are the first casualties in corporate cutbacks.

Box 6 Practical issues regarding employer involvement in masters-level education

Establishing a new programme of education will require considerable resource in time and money, and any employer must think very carefully before proceeding. Some of the issues to be considered are discussed.

What is the business need?

This is the single most important question, and is well understood today. Each organisation will need to review its individual situation and determine whether there is a clear benefit to be derived from the sponsorship of a particular programme of education. Sometimes the issues are relatively straightforward – there may be a vital skills gap that cannot be met any other way. In other cases, the matter is less clear and a decision on whether to proceed might be affected by less tangible factors, such as the impact a new programme might have on the firm's image in the jobs market. Increasingly, larger corporates adopt a variety of arrangements, which may include some programmes tailored in collaboration with HEIs, some individuals being supported to attend open programmes, and some in-house training.

Assessing demand and supply is critical (for both/all parties). This is perhaps something that could be addressed in partnership with/by RDAs, Sector Skills Councils (SSCs), Trade Associations and perhaps even the regional Science and Industry Councils).

Is a suitable programme already available?

Given the large number of institutions offering employer-sponsored courses, and the range of programmes already on offer, there may well be an existing programme that will meet the need. This might even be a programme which is currently closed, but where the sponsoring employer is looking for new partners to help shoulder the costs.

Sustainability

A key issue is whether a proposed programme will be sustainable. Managers may be calling for a tailored programme to meet a current business need, or a major technological change facing the organisation. But if internal demand will dry up in a few years, this may prove a waste of resources. Sustainability may be enhanced by seeking other companies to share in the development of the programme, or ensuring that the programme is wide enough to attract other companies into sponsorship a few years down the line when the initial need has been met.

Relevance to the company's work

A programme may include a practical project or dissertation that could address a real problem facing the employer organisation. The employer may also ensure that the course material is relevant to its work through involvement in the programme's steering group.

Involvement of other employers

Some courses are established for the employees of a particular organisation, others for a group of organisations or are simply open to all-comers. A course restricted to the employees of a single organisation may offer the employer greater influence over the course content, and there may be greater freedom to include commercially sensitive material, but it is also likely to be a more expensive option. Where a programme is open, the costs should be reduced and there are also greater opportunities for employees (and managers, through involvement in a Steering Group) to share ideas and network with a wider group.

Particular problems of smaller employers

It is rarely open to a smaller employer to establish a customised programme, but groups of such firms may collaborate with an HEI to meet a particular need, with significant benefits. A good example of this was the establishment of the *PG Certificate in e-learning design* by the University of Sussex. This followed discussions between the University and a commercial network representing digital media businesses which recognised that there might be 1,200 small enterprises in the region – vital to its local economy – which might have training needs. The underlying needs analysis was partly funded by a grant from the local Council which had a significant stake in attracting and retaining such businesses in the area.

Accreditation

While some employees may be attracted by a programme leading to an MSc or other degree, there is considerable variety.

- Some courses offer diplomas or certificates.
- Some degree programmes offer diplomas or certificates to students who complete only part of the course.
- Some programmes are modular, or very short, and offer no accreditation.
- Some are accredited by organisations other than HEIs.

Indeed, while some employees may express a wish to add a further degree to their CVs, others find the burden of attending a part-time degree course, on top of a demanding job, incompatible with their other personal commitments, and so may be attracted by a flexible programme, or the opportunity to dip their toe in the water before committing to a full degree (see BT MSc at box 3).

Choosing the right HEI

This is another key decision, and in some cases the company puts the matter out to tender (see Amex course at box 1 above). Some larger companies, which sponsor several programmes, make all their arrangements with a few HEIs which have been identified as having particular expertise in the relevant fields. In other cases, a company may require that academics from two or more HEIs collaborate to deliver the course programme.

Encouraging HEIs to be flexible

Engagement with employers has taught HEIs to be flexible in course design, to timetable the programme to be compatible with students' employment obligations and in some cases to speed up the process for changing the syllabus to reflect rapidly changing employer needs in response to technological change.

Method of delivery

While programmes are typically delivered face to face, there is now scope to deliver material electronically (for example the BT MSc at box 3). This enables employers to offer the same programme simultaneously across the globe.

5.6 Recommendations

- More emphasis must be given to a collaborative approach to learning between universities and industry, including employer engagement with curriculum development, matching the emphasis that has already been placed on knowledge transfer and commercialising research.
- We specifically encourage work experience as part of HE qualifications, and we call upon students, government, universities, and industry to engage to take advantage of the mutual benefit arising from such opportunities.

6 What is the balance between UK and non-UK students?

This chapter focuses on the increases in non-UK domiciled students who choose to come to the UK to study. The rise in the number of non-UK students undertaking UK stand-alone masters qualifications is highlighted as a particularly strong trend.

6.1 International flows of STEM students and professionals

There is a healthy flow of students, researchers and academic staff into the UK, which has a positive impact on STEM teaching and research. There is also an outward flow of STEM students and professionals from the UK to other countries, including other European countries, the US, and Australia. These international flows offer a range of benefits, including knowledge sharing, providing education that is not on offer in a student's home country, and building up capacity overseas through education in UK.

The UK is a popular destination for overseas students, second only to the United States in terms of the percentage of overseas students enrolled. The UK received 12% of the world total of foreign students in 2005, while the US received 22%[7] (OECD 2007).

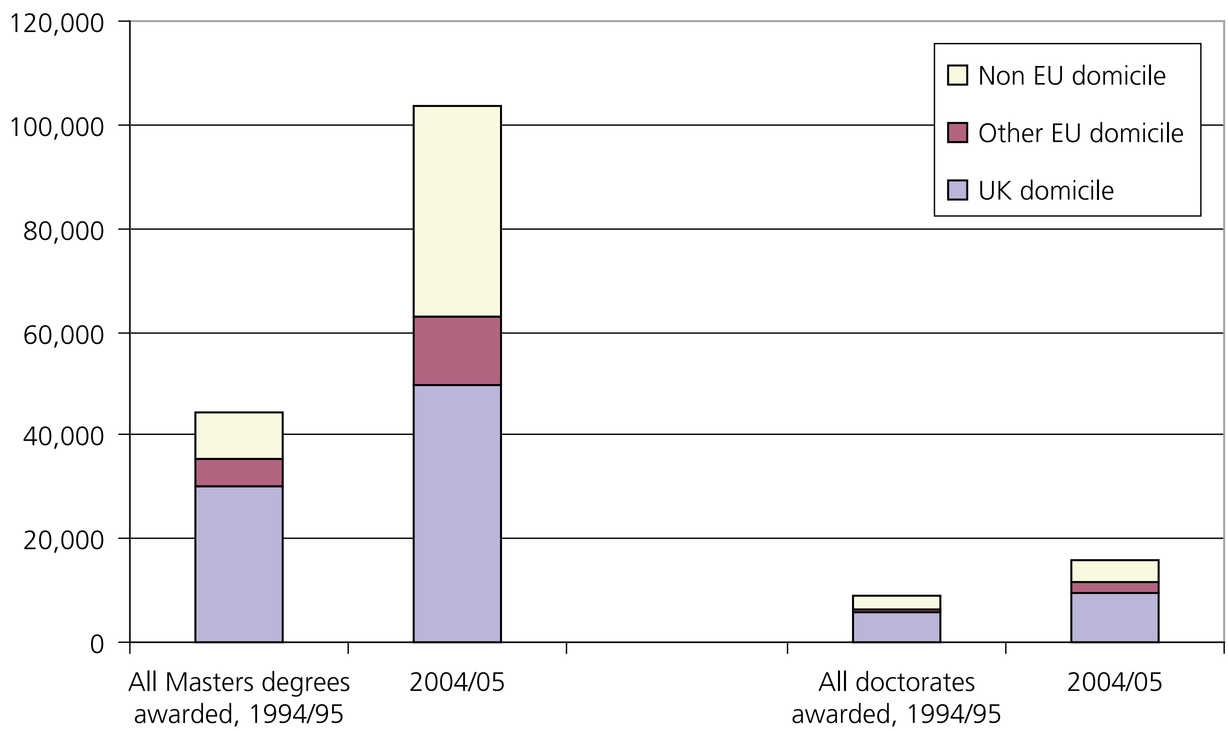
The UK is also a popular destination for academic professionals from overseas. A recent report by Universities UK reveals the extent of these international flows: in 2005/06 19.1% of academic staff working in the UK were non-UK nationals, Additionally 27% of all academic staff appointed in 2005/06 in the UK were non-UK nationals (Universities UK 2007b).

6.2 Non-UK students studying in the UK

Figure 6.1 shows the balance between the three categories of UK-domiciled students, other-EU domiciled students, and non-EU students at masters and doctorate level in 1994/95 and in 2004/05. The most immediately striking finding is the impressive rate of growth in the number of stand-alone masters degrees[8] and doctorates awarded to students of any nationality: up by 133% (to 103,500) and 79% (to 16,000), respectively, between 1994/95 and 2004/05. A major finding is the sharp rise in the number of non-EU students undertaking masters in the UK during the ten-year period.

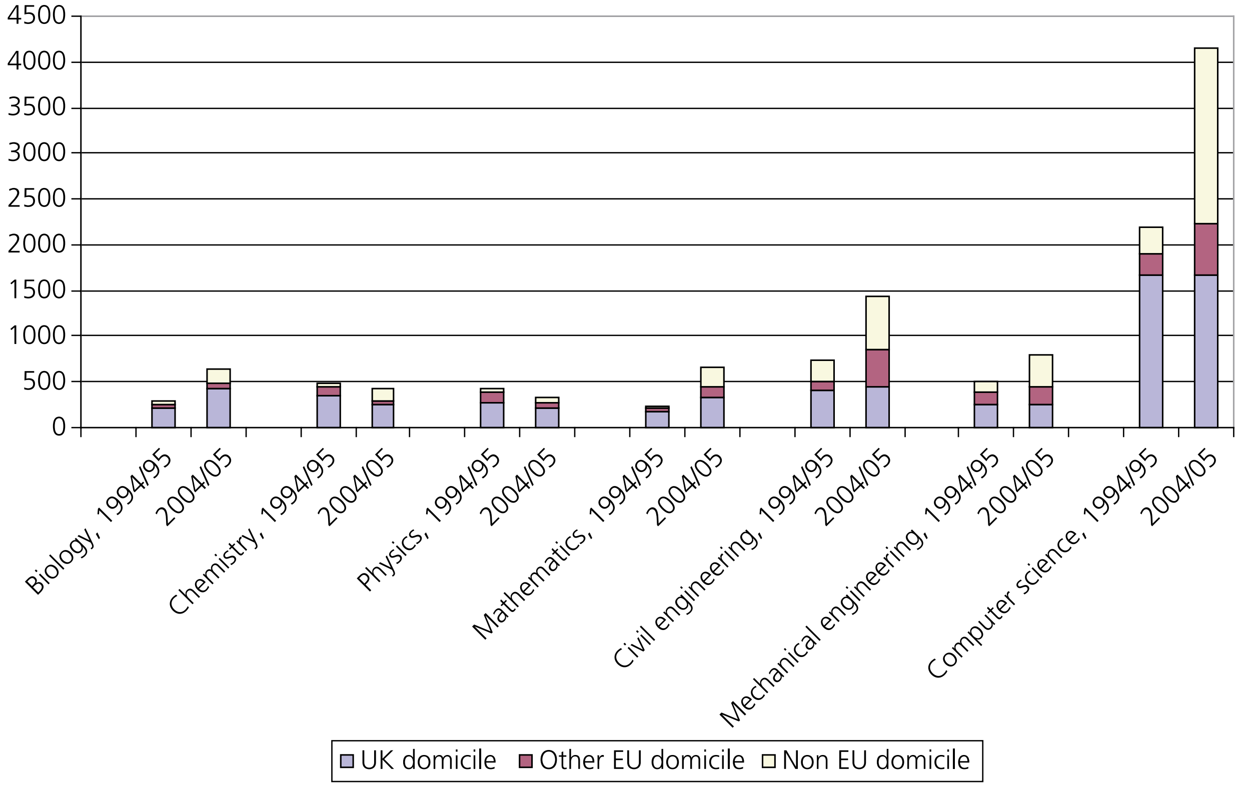
Figure 6.2 shows the domicile balance in selected science subjects at masters level in 1994/95 and in 2004/05. In all

Figure 6.1 Masters and doctorate graduates by domicile, 1994/95 and 2004/05 (HESA data).



[7] Down from 26% in 2000.
[8] This does not include 4-year courses like the MMath or MPhys, which are classified as first degrees.

Figure 6.2 Masters graduates in selected science subjects by domicile (UK, other-EU and non-EU), 1994/95 and 2004/05 (HESA data).



subject areas, there have been increases in the percentage of non-EU students over the period, although the size of this increase varies significantly between subjects – for example, biology has a much smaller increase than computer science. In some subjects, such as chemistry and mechanical engineering, there has been no increase in the number of UK students studying for masters throughout the period. The percentage of other-EU students has increased in some subjects – eg civil engineering – over the period, and declined in other subjects such as physics.

The domicile balance at doctorate level is shown in Figure 6.3. Again, many subjects have seen an increase in the number of non-EU domiciled students, although often there was already a considerable number of non-EU students in 1994/95. The number of other-EU students has also risen in all subjects during the period. In 2004/05 in engineering and computer science subjects, UK students made up less than 50% of those undertaking doctorates in the UK. The rise in numbers of other-EU students is also relatively large.

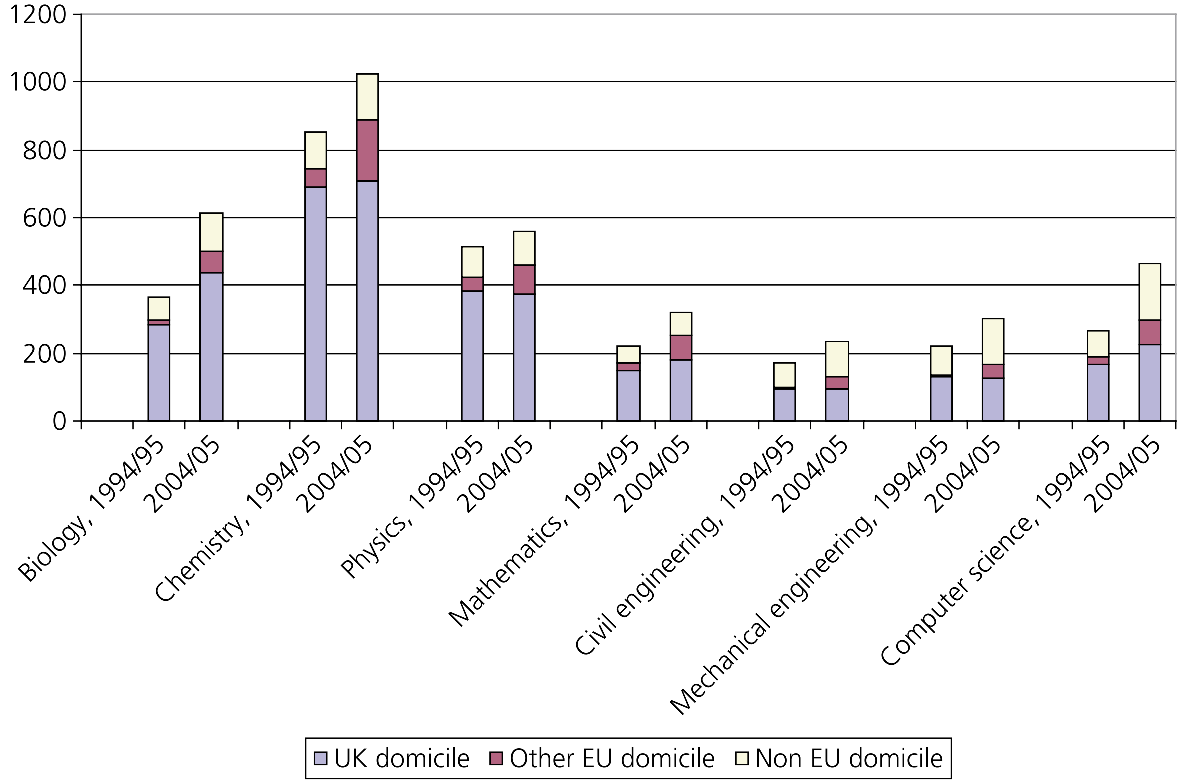
Stand-alone masters are a valuable source of income for UK HEIs. Non-UK students who currently come to the UK to study these courses are attracted, inter alia, by the conduct of HE in English and by the one-year masters degrees. However, the UK's natural advantages may be at risk with the growth of English-language instruction in STEM subjects in non-English speaking countries.

Inflows of non-UK students are healthy also for the STEM-based industries that recruit from this group, and provide flexibility in meeting demand where there are supply shortages. The UK could, however, be vulnerable to skills shortages if low numbers of UK-domiciled students study particular subjects, and if many non-UK domiciled students do not stay in the UK to work following the completion of their qualification.

The increase in non-UK students can advance the economic competitiveness of the student's home country in the long term, by equipping their students with relevant skills ie capacity building. UK HEIs can make money from this in the short term, yet the present demand from foreign students may not be sustainable. In the long term this demand may be vulnerable as countries build up their own knowledge base.

Non-UK students provide a valuable source of income for UK universities. A study by the Higher Education Policy Institute found that in 2003/04, fees from non-EU students accounted for 8.1% of the total income of HEIs in England (HEPI 2007). This can be an extremely important income stream for UK universities, especially as they have complete control over how they spend this

Figure 6.3 Doctorate graduates in selected science subjects by domicile (UK, other-EU and non-EU), 1994/95 and 2004/05 (HESA data).



money – there are no strings attached, as can be the case with some funding streams. The HEPI study explores the recent rapid increase in fee income, but warns that HEIs cannot assume that this growth will continue.

The HEPI study also explores the international market for higher education, which it says must be considered an immature market at present, because the explosion in numbers is so recent. Therefore it is not yet known which countries, and which HEIs within those countries, will establish a lasting reputation in overseas markets. It is also difficult to predict which countries will continue to supply large numbers of students in ten or twenty years time. It will take time for information about the returns gained from undertaking a qualification at an English university to become known in major source countries such as China, India or Malaysia. HEPI also predicts that, over time, in-country provision in major source countries will become more competitive and so some students will choose to study in their own countries where previously they may have opted for overseas study. Also, sudden political or economic shocks (which by their nature may well be unforeseen) could have a significant impact on numbers of overseas students from particular countries.

The implications of changing student demographics are complex, and have ramifications outside of the HE sector. Some of the students travelling from outside the UK will seek to remain in the country, especially if they can find appropriate jobs and an employer who will sponsor them through the visa process. In this way, some employers can seek to fill any potential UK skills gaps. However, for employers such as the Ministry of Defence, where for security reasons the policy is to employ only UK nationals, the predominance of non-UK domiciled students in subjects like computer science and mechanical engineering may cause problems.

The fact that so many students – some of whom will subsequently achieve positions of influence in their home countries – have close contact with the UK during their formative years constitutes an important opportunity for the UK to establish a network of relationships of long-term significance.

6.3 Other aspects of international engagement by UK universities

In addition to non-UK students coming to the UK to study, there are many other ways in which UK universities can engage with the increasingly globalised HE scene. For instance, UK universities can form a variety of partnerships with overseas universities. Examples of these include initiatives such as the setting up of overseas campuses or summer schools. Courses in UK universities may also work in partnership with overseas universities.

Other international factors and processes in higher education will also have an effect on UK higher education. The Bologna Process is one such example, and is considered in more detail in Chapter 4. The European Research Area (ERA) and the European Research Council (ERC) will also have an impact, especially now that the ERC is engaged in the process of distributing research funding. The creation of the European Institute of Technology will also have an effect on science and innovation throughout Europe.

6.4 Recommendation

- The UK's ability to attract increasing numbers of overseas students is a real success story in terms of global influence. It attests to the competitiveness of the UK HE system and makes an important financial contribution. But other countries are increasingly active in this market. We therefore recommend that a national impact assessment be undertaken to allow the sector to identify the risks and possible consequences of the current pattern of growth being reversed.

7 Recommendations and conclusions

The introduction to this report set out the challenges facing the UK in the coming years. In order to maintain a world class HE system able to compete in a changing world and able to respond appropriately to a range of challenges, we have made several major recommendations throughout Chapters 3 to 6. These are discussed below, with reference to Chapter 2, which set out the specific long-term issues confronting UK HE.

7.1 Course content

Degrees in traditional core sciences provide a sound foundation for those who proceed to STEM careers, and they may also provide a high level of practical, analytical, mathematical and modelling skills for those who pursue other careers. A large pool of students undertaking STEM subjects in the UK is a strength – with the UK able to thrive in a flexible global marketplace through having a good supply of STEM graduates who are able to cope with changes in demand for professional scientists, and who are able to take up several non-STEM specific careers if they choose to do so, and if the demand exists.

We support the HEFCE-funded programmes that aim to increase uptake in key STEM subjects at undergraduate level. However, the need for science skills is not only at undergraduate level, and in future there may be a need to stimulate demand for particular postgraduate science courses and qualifications.

Science often proceeds by interdisciplinary work, and this may be achieved very effectively by specialists in different areas working together. It is therefore vital that many STEM students have a traditional single-subject STEM undergraduate qualification. But there are clearly benefits to some individuals having an inter-disciplinary background, and in our experience this is more appropriate to two-year masters-level study built upon a foundation of core science degree at initial degree level. As explored in Chapter 4, the emerging area of systems biology provides an example of this. The Royal Academy of Engineering and Academy of Medical Sciences report *Systems biology: a vision for engineering and medicine* considered the education and training that will be required to enable the UK to compete successfully in systems biology. It recommended that undergraduates continue to be trained in a core discipline, but that they should be exposed to problems and interaction with peers from other disciplines. The report suggested that final year undergraduate courses or masters degrees in life sciences could include discipline-hopping modules in engineering, mathematics or the physical sciences and vice versa.

Alternatively, some students will undertake broader science programmes at first degree level, which can offer several potential benefits. However, the evidence to date indicates that it is very difficult to devise a broader science degree that has coherence and sufficient depth to ensure equivalence of esteem with traditional core disciplines. Nevertheless, we support the development of these qualifications, and hope that broader first degrees in science prove to be useful and robust qualifications in the coming years. We believe the existence of a wide range of science qualifications at first degree and postgraduate levels is a good thing.

The increase in the proportion of UK students who now attend HE has meant that a broader range of individuals are now undertaking HE courses. The HE system has had to respond to this, for example by providing a more diverse range of courses or a greater variety of modes of study. With this diversity of courses, it is important to ensure that pathways and links between different types of courses exist, and that for instance, a student who has studied a broader science degree can move into more specialised STEM subject study if s/he is qualified and motivated to do so

STEM HE courses can also fulfil wider functions. In a general sense science courses should teach students scientific literacy and an understanding of the scientific method. Many political, economic and social challenges involve science in one shape or another, and therefore the existence of several individuals who are familiar with science, and who are able to approach issues from a scientific perspective, can only be advantageous. Higher education courses in STEM (and other) subjects, should also play a vital role in teaching people to think, and to utilise their skills of critical thinking. In this wider sense then, HE has an essential role in producing individuals whose skills enable them to thrive in a range of careers in addition to enabling them to participate fully in a democratic society.

The content of STEM courses in higher education will build upon the science taught within secondary schools – the skills and abilities with which students enter HE will inevitably influence the content of undergraduate science courses. Changes over time at the school level – for example, in curriculum, teaching methods or assessment – will affect how science is delivered at undergraduate level. Therefore, when changes to science at secondary school level are being considered, it is vital that the possible impact of these changes on HE is fully borne in mind.

- Single subject first degree courses must be protected as a vital part of the HE experience. (C4)
- At the same time, we believe that broader courses covering a wider range of science subjects should continue to be developed, as they may prepare people to be scientifically literate citizens. (C4)
- When changes to school-level qualifications and courses are proposed and implemented, the needs of students entering STEM HE, particularly with respect to mathematical skills, must be explicitly taken into account. (C4)

7.2 Course structure

As discussed in Chapter 4, we recommend that, for students going on take doctorates, the complete higher education cycle should normally take about eight years full-time study from the start of the first degree (ie in many cases about one more year than at present). However it is vital to retain the current flexibility of the UK degree system, to enable students to complete their studies within the timeframe that best suits their individual circumstances and to add the extra time at the point to suit their future aims. This flexibility must include provision of both one-year and two-year full-time equivalent masters course, since both offer advantages in particular circumstances.

The additional time could help to address concerns from employers that students need more knowledge, and worries of undergraduate course tutors about the need to cover a very wide range of material. At postgraduate level, extra time could increase the opportunity to ensure that masters courses fulfil their purpose: a vocationally focused masters can be excellent training for a particular career, while a research-based masters qualification can prepare students for further academic or industrial research. Extra time would also address concerns that UK students are sometimes viewed as less mature and knowledgeable when compared with their European counterparts, as found in EPSRC international reviews[9] (EPSRC 2007).

An additional year at masters level would have the great advantage of enabling the UK to fit clearly into the framework recommended by the Bologna Process. There are obvious benefits to being Bologna-compatible. Non-UK students will be able to choose the UK as a destination in which to study a Bologna – compatible qualification. Additionally, UK students who choose to work or pursue further study such as a PhD outside of the UK, would benefit from having a Bologna-compatible qualification. Industry would also value a higher level of education that matches international levels.

An extended period of study will have significant cost implications, both for the HEIs and for the students. The Government must be prepared to take action on any funding issues that arise from changes in course structures, and to ensure that the courses within the current structure are properly funded. If any changes are to be made to the length of time it takes to complete qualifications, the Government must ensure both that universities receive sufficient funding, and that students are adequately supported financially for the full duration of their course.

At present, some STEM subjects offer integrated master (IM) qualifications: a four-year first degree which takes students up to the equivalent of a first degree followed by a stand-alone masters qualification. We believe that IM degrees serve useful purposes and should be retained. They are an effective response to the changing intake and changes in the subject disciplines.

Whether a masters qualification takes one or two years to complete, we stress the importance of students being adequately funded. A separate point is that full consideration of the funding available to masters-level students is especially important as research councils in the UK are progressively withdrawing from offering masters funding, thus leaving a serious funding gap between undergraduate and doctoral study. Efforts to increase and widen participation at first degree level will be undermined if the most capable students are then unable to undertake masters due to a lack of funding.

- To meet international standards, formal higher education in STEM subjects should normally take the equivalent of eight years full-time study from starting a first degree to finishing doctoral study. (C4)
- It is vital to retain flexibility in how the eight years are structured. The current diversity of course types is a strength of the UK HE system. Future structures must accommodate the needs of those not intending to proceed to the doctorate phase. (C4)
- It is essential that all phases in the 8-year programme of study are properly funded. (C4)
- We recommend that the current four year initial degrees in the physical and mathematical sciences and engineering (‘integrated masters’ degrees) remain for the foreseeable future as an effective response to the changing intake and changes in the subject disciplines. (C4)

[9] For example, the EPSRC international review of mathematics in 2004 found that ‘six years from entering university to getting a PhD almost inevitably induces a narrow training; bringing the British system in line with the perspective offered by the Bologna agreement should be considered.’

7.3 Supply – student numbers

The number of first degrees obtained in physics by UK-domiciled students has remained relatively stable throughout the past ten years. The numbers of biology and mathematics degrees obtained have fluctuated more over the period, yet by the end of the decade the number of degrees obtained was similar to the start of the period. However, there has been an overall decline in the number of chemistry graduates over the same period. We need to encourage more people to take up STEM subjects where in the past ten years the output has at best remained flat against a background where other subjects have increased by 20%.

The number of stand-alone masters in these core STEM subjects has not increased in line with the 65% increase seen across all subjects in the number of UK-domiciled stand-alone masters students. However, once integrated masters are added into the equation we can see that there have been considerable increases in the numbers of STEM masters-level qualifications undertaken during the time period.

Meanwhile, the number of doctorates undertaken by UK-domiciled students in these core STEM subjects has remained relatively stable throughout the period. The fact that there has not been any increase here – to match the increases noted above at both first degree and masters level – could show a high demand from employers for students with masters-level qualifications, who therefore enter the workplace with a masters qualification, rather than continuing with doctoral level study. However, the stable number of doctorates could also reflect the level of funding available to doctorate students. If the funding is not available, students who may otherwise have undertaken a doctorate may instead enter the workplace.

To be globally competitive in 2015 and beyond, the UK will need a strong supply of students studying STEM subjects at all levels, including beyond first degree level. Therefore, Government action to encourage and enable STEM study at postgraduate masters and doctorate may be required in future, if the UK is going to compete successfully with highly skilled economies around the world, who have increasingly high levels of individuals with postgraduate-level STEM skills.

In order to encourage the best-suited students to study STEM subjects at all levels, financial incentives to potential students may be required. Student debt, including the repayment of tuition fees, is now a widespread factor of student life, and in this environment students' choices will be likely to depend, at least in part, on financial considerations. Financial incentives, such as bursaries or reduced fees for particular subjects, could therefore be vital factors in encouraging students to study particular subjects.

An essential element of increasing uptake in STEM subjects is the availability of courses in these subjects: students can study only those subjects that are available. In some STEM subjects a recent trend of 'desertification' has taken place – the closing down of departments in some STEM subjects to create regional 'deserts' where particular subjects are not available across a geographic region (this is explored in section 5.3 of *A degree of concern?)*. We therefore recommend that universities and the Government take steps to ensure that STEM subjects are available regionally throughout the UK. This is especially important in the context of current efforts to widen participation in HE. Several potential students will be unable to, or may simply prefer not to, leave their particular geographical area, due to factors such as family commitments, cultural or financial pressures. Therefore if particular subjects are not available in that region those subjects are simply not a viable option for some students.

An important element of reversing the desertification trend is to ensure that STEM departments are treated fairly within the HE funding mechanism, and do not appear as loss-making if there are sufficient levels of student demand. The current transparent approach to costing (TRAC) teaching exercise should help ensure that HEFCE funding levels better reflect the true costs of teaching.

Informed student choice is vital to ensure a healthy supply of STEM students. Good careers advice at secondary school level can play a major role in informing students of the benefits of studying science subjects at university, such as the range of career opportunities that will be open to them.

We have identified a striking increase in the numbers of non-UK domiciled students choosing to study in the UK. This is a powerful vote of confidence in the UK HE system and a great opportunity for UK influence around the world. Whether the UK can maintain its competitive advantage as other countries develop English-language postgraduate courses and as the quality of HE in the countries of origin improves is another matter: students may no longer need to travel abroad or may travel to other destinations than the UK. Indeed, some other countries are now increasing their intakes of foreign students even faster than the UK. So the UK must offer in-coming students an excellent university experience if they are to think their UK HE experience is worthwhile academically, financially, and in other respects.[10]

[10] Recent research carried out for the Council for Industry and Higher Education (CIHE) found that overseas students at UK universities often find it difficult to integrate socially with UK-domiciled students (CIHE 2007).

- To avoid serious shortages in vital skills sets, we believe that positive action is needed by individual universities and by central Government to encourage study in core science subjects at all levels by the introduction of bursaries, reduced fees or other incentives for students undertaking these important courses. (C3)
- We also recommend that specific steps are taken by individual universities and by central Government to deliver STEM HE on a regional basis, with a priority to review areas where provision has recently changed. (C3)
- Funding should be made available for the HE sector, professional bodies, learned societies and other stakeholders to do more to advertise the benefits accruing to those with STEM skills. (C3)
- The UK's ability to attract increasing numbers of overseas students is a real success story in terms of global influence. It attests to the international competitiveness of the UK HE system and makes an important financial contribution. But other countries are increasingly active in this market. We therefore recommend that a national impact assessment be undertaken to allow the sector to identify the risks and possible consequences of the current pattern of growth being reversed. (C6)

7.4 Demand – the relationship between HE and employers

The future demand from employers for STEM graduates is difficult to predict, as unexpected events inevitably occur. However, it is important, as far as possible, to build up a quantitative picture of the future demand of employers, and also to understand what skills, knowledge and experience they seek in the STEM graduates they employ, and possible future changes in this. However, as future demand is difficult to predict, a major requirement will be to have graduates who have transferable skills, and who can adapt to the economic demands of the future.

It is vital that potential HE students know the benefits that they will accrue if they choose to undertake STEM study at HE level. Secondary school students who are considering whether to attend HE, and what course of HE study to undertake, should be fully aware of the range of career options STEM HE study can bring about, and also the financial rewards that STEM graduates can enjoy. Schools, universities and employers all have a role to play in ensuring potential students are aware of the benefits STEM study at HE can bring about. The Science Council and SEMTA are two examples of organisations who have publicised the benefits of STEM study.

There are many ways in which universities and employers work together. In Chapter 5 we examined one of these ways in more depth – namely where employers are involved in the provision of a masters-level course. Postgraduate education and training designed or sponsored by employers meets a very real need and should be viewed as an integral part of the educational framework. These programmes offer benefits to all three parties involved: students, employers and HEIs. Any future official review of STEM HE should include such education and training to help ensure its continuation and development. In his report on skills Leitch also stressed the need for universities to be responsive to the needs of employers who want to deliver degrees in the workplace or to provide bespoke training for highly skilled workers (HM Treasury 2006b).

HEIs and employers designing a new course of postgraduate education and training should ensure that the market is broad enough to sustain the course for a worthwhile period of time. This will entail undertaking a full and thorough assessment of likely future student demand. For these courses to be of benefit to both universities and employers, both parties must clearly articulate what they want the course to provide. Employers must articulate clearly their needs and expectations, including what knowledge and experience they want graduates from the course to possess. HEIs meanwhile must be realistic about what they can offer and deliver. The negotiations that take place between partners over issues such as collaborative and contract research and full economic costing (FEC), should enable all parties to understand each other's perspectives and concerns. Intermediaries such as Sector Skill Development Agencies and Councils, Regional Development Agencies and Trade Associations could play a vital role here.

We have noted that SMEs, acting alone, may lack the resource to establish postgraduate education or training for their employees. Therefore those who are responsible for enterprise, innovation and employment issues on a regional basis, such as RDAs, SSDA, SSCs and Trade Associations should ensure that there are arrangements to meet the particular requirement for postgraduate education and training for employees of SMEs. In his review of business-university collaboration Lambert recommended that 'The Government should ensure that SSCs have real influence over university courses and curricula. Otherwise, they will fail to have an impact on addressing employers' needs for undergraduates and postgraduates.'

Curriculum design is a further issue in which employers can engage with universities. There are of course many different stakeholders and viewpoints that must be considered when courses are being designed, of which employers are just one. However, if courses are to provide graduates who have the skills and knowledge sought by employers, it is vital that employers are involved in course design.

Another way in which universities and businesses collaborate is through students undertaking placements in industry throughout their higher education study. Employers place a high value on the practical skills and industry experience. We believe that various steps should be taken to increase the practical experience of those taking first degrees, and fully support those courses which offer a year or shorter period working in industry as part of a first degree.

However, while employer engagement in universities has many benefits, there are also limits or drawbacks, which both universities and businesses must consider carefully. Lambert's report found that 'Businesses in certain specialised disciplines, such as medicine, engineering and architecture, express their skill needs through professional bodies which define the academic requirements of courses. Several employers say that these mechanisms for accreditation, particularly in subjects such as engineering, can serve as a 'dead hand' by constraining innovation and making it difficult for universities to respond more quickly to specific business needs.' (HM Treasury 2003, Section 8.9)

Of course, it is not just private businesses that affect and get involved with the provision of STEM higher education. There are also numerous links and interdependencies between the public sector and universities.

The supply of science teachers is of crucial importance to the public sector, as is the supply of Government scientists. The Royal Society's report *The UK's science and mathematics teaching workforce* (Royal Society 2007) analyses key trends, and assesses the quality of data available, concerning science and mathematics teacher supply and retention. Changes to career structures in the public sector will also affect the choices students make in HE. For example a qualification or level of study may be a prerequisite to enter a particular public sector career.

Universities have long collaborated with employers on research and, indeed, are encouraged to seek research income from businesses. However, businesses can usefully engage with universities on aspects other than research, in particular on teaching and learning. The involvement of employers in teaching can provide excellent opportunities for both businesses and universities to share knowledge and skills. In practice, this could entail an individual from a business teaching a relevant part of a course, or being actively involved in the designing of a course.

It is not simply the case that the demand for graduates will influence the supply of STEM graduates: conversely, the supply of graduates can also affect demand. Supply can stimulate demand in that an increase in the number of STEM PhD graduates, for example, may lead to an increasing number of these graduates setting up their own businesses, as individuals or in collaboration as a group. If successful, these businesses will in time expand and therefore create further demand for individuals with STEM (and other) skills. If several graduates from one university do this in the area in which the university is based, there may well be a concentrated geographic effect. Several start-ups by graduates in a particular area will have a strong positive effect on the local economy if the businesses thrive.

- The UK Commission for Employment and Skills should undertake a detailed study of employers' needs for high level STEM skills and knowledge and also of the extent and nature of current and likely future mismatches between supply and demand. (C3)
- More emphasis must be given to a collaborative approach to learning between universities and industry, including employer engagement with curriculum development, matching the emphasis that has been placed on knowledge transfer and commercialising research. (C5)
- We specifically encourage work experience as part of HE qualifications, and we call upon students, Government, universities, and industry to engage to take advantage of the mutual benefit arising from such opportunities (C5)

8 References

Bell H (University of Oxford). Personal communication, 4 December 2007

CBI (2005a). *Innovation survey 2005*. CBI: London

CBI (2005b). CBI response to Leitch review of skills. CBI: London

CIHE (2007). *Global Horizons for UK students: A guide for universities*. CIHE: London

DfES (2006). *The Supply and Demand for Science, Technology, Engineering and Mathematics Skills in the UK Economy* (Research Report RR775). Department for Education and Skills: London

DTI (2003). *UK Competitiveness: moving to the next stage*. DTI: London

DTI (2006). *Science, Engineering and Technology Skills in the UK, DTI Economics Paper No 16*. Department for Trade and Industry: London

EPSRC (2007). International reviews. Available online via: www.epsrc.ac.uk

Engineering Council (2000). *Measuring the Mathematical Problem*. Engineering Council: London

Engineering and Technology Board (2000) *Measuring the Mathematical Problem*. Available online via: www. etechb.co.uk

Fulford S (EPSRC). Personal communication, 4 September 2007

Futuretrack (2007). Interim report. Available online via: www.hecsu.ac.uk

HEFCE (2006). Strategically important subjects: STEM funded projects aimed to help increase uptake in key STEM subjects: Chemistry for our future – RSC; Stimulating physics – IoP; more maths grads – CMS; and London engineering project. Information available online at: www.hefce.ac.uk/aboutus/sis/stemprojs/

HEFCE (2007a). Survey of interaction between universities and businesses. Available online at: www.hefce.ac.uk/reachout/hebci/

HEFCE (2007b). RAE plans for post 2008. Available online via: www.hefce.ac.uk

HEPI (2007). *The Academic Experience of Students in English Universities (2007 report)*. Available online at: www.hepi.ac.uk/pubdetail.asp?ID=240&DOC=reports

HM Treasury (2003). *Lambert review of business-university collaboration*. Available online at: www. hm-treasury.gov.uk/consultations_and_legislation/ lambert/consult_lambert_index.cfm

HM Treasury (2004). *Science & innovation investment framework 2004–2014*. HM Treasury, Department for Trade and Industry, Department for Education and Skills: London

HM Treasury (2006a). *Science & innovation investment framework 2004–2014: Next steps.* HM Treasury, Department for Trade and Industry, Department for Education and Skills, Department of Health: London

HM Treasury (2006b). *Leitch review of skills*. Available online at: www.hm-treasury.gov.uk/ independent_reviews/leitch_review/review_ leitch_index.cfm

House of Commons (2007). *Education and Skills Select committee report on the future sustainability of the higher education sector*. Parliament: London

IET (2007). *Skills survey*. Available online via: www.theiet.org

Jevons F (1967). *A 'Science Greats' course.* Physics education **2** (4), 196–199

Jiao Tong University (2006). *The academic ranking of world universities.* Institute of Higher Education, Shanghai Jiao Tong University: Shanghai

Massachusetts Institute of Technology (2007). *The International Genetically Engineered Machines (IGEM) competition*. Available online at: http://parts2.mit.edu/wiki/ index.php/Main_Page

NAS (2005). *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, February 2006 version. National Academy of Sciences: Washington

National Audit Office (2007). *Staying the course: The retention of students in higher education.* NAO: London

OECD (2007). *Education at a glance*. OECD: Paris

PricewaterhouseCoopers LLP (2005). *The economic benefits of higher education qualifications: A report produced for The Royal Society of Chemistry and the Institute of Physics.* PricewaterhouseCoopers LLP: London

Qualifications and Curriculum Authority (2007). Core subject level criteria within the A-level syllabuses. Available via: ww.qca.org.uk

R&D Society (2006). *Higher Education in 2015 and beyond: will it meet our needs?* R&D Society: London. Available online via: www.rdsoc.org/grads2015.html

RAEng (2006). *Educating engineers for the 21st century: the industry view, a commentary on a study carried out by Henley Management College for The Royal Academy of Engineering.* Royal Academy of Engineering: London. Available online at: www.raeng.org.uk/education/ee21c/default.htm

RAEng & AMS (2007). *Systems biology: a vision for engineering and medicine*. The Royal Academy of Engineering and the Academy of Medical Sciences: London

Roberts G (2002). *SET for success: the supply of people with science, technology and mathematics skills*, The Report of Sir Gareth Roberts' Review, April 2002. Available via: www.hm-treasury.gov.uk

Robbins L (1964). *The Robbins Report: Higher Education in Britain*

Royal Society (2006a). *A degree of concern? UK first degrees in science, technology and mathematics*. The Royal Society: London. Available online at: www.royalsociety.org/document.asp?tip=0&id=5467

Royal Society (2006b). Response to DfES consultation on research assessment. Available online at: www. royalsoc.org/document.asp?tip=0&id=5035

Royal Society (2006c). *Submission to the House of Commons Education and Skills Committee inquiry on the Bologna Process*. Available online at: www.royalsociety.org/document.asp?tip=0&id=5884

Royal Society (2007). *The UK's science and mathematics teaching workforce*. A 'state of the nation' report. Royal Society: London. Available online via: www.royalsociety.org/education

Smith A (2004). *Making mathematics count: the report of Professor Adrian Smith's inquiry into post-14 mathematics education.* Department for Education and Skills: London

THES (2007). *World university rankings.* The Times Higher Education Supplement: London

Thompson N (1992). A discussion of the history of the department of physics in Bristol: 1948 to 1988. Available online at: www.phy.bris.ac.uk/history/07.%20Thompson's%20History.pdf

UCAS (2007). Applications to STEM courses. Available online via: www.ucas.ac.uk

UK Europe Unit (2007). Objectives of the Bologna Process. Available online at: www.europeunit.ac.uk/bologna_process/objectives_of_the_bologna_process.cfm

Universities UK (2007a). Strategic Foresight Project: interim report (unpublished)

Universities UK (2007b). *Talent wars: the international market for academic staff*. Available online via: www.universitiesuk.ac.uk

University of Cambridge (2007). *Natural Sciences*. University of Cambridge: Cambridge

9 Glossary and Acronyms

ABPI	Association of the British Pharmaceutical Industry
AMS	Academy of Medical Sciences
CBI	Confederation of British Industry
CIHE	Council for Industry and Higher Education
CMS	Centre for Mathematical Sciences
CPD	Continuing Professional Development
DCSF	Department for Children, Schools and Families
DELNI	Department for Education and Learning Northern Ireland
DfES	Department for Education and Skills
DIUS	Department for Innovation, Universities and Skills
DLHE	Destinations of Leavers from Higher Education
DTI	Department for Trade and Industry
EPSRC	Engineering and Physical Sciences Research Council
ERA	European Research Area
ERC	European Research Council
ETB	Engineering and Technology Board
EU	European Union
FDS	First Destination Supplement
FE	Further Education
FEC	Full Economic Costs
HE	Higher Education
HE-BCI	Higher Education-Business and Community Interaction
HEFCE	Higher Education Funding Council for England
HEFCW	Higher Education Funding Council for Wales
HEI	Higher Education Institution
HEPI	Higher Education Policy Institute
HESA	Higher Education Statistics Agency
HND/HNC	Higher National Diploma/Higher National Certificate
HMT	Her Majesty's Treasury

ICT	Information and Computer Technology
IET	Institute of Engineering and Technology
IOP	Institute of Physics
NAS	National Academy of Sciences
OECD	Organisation for Economic Co-operation and Development
OSI	Office of Science and Innovation
PGCE	Postgraduate Certificate in Education
QCA	Qualifications and Curriculum Authority
QR	Quality-related
RAE	Research Assessment Exercise
RAEng	Royal Academy of Engineering
R&D	Research and Development
RDA	Regional Development Agency
RSC	Royal Society of Chemistry
SEMTA	Sector Skills Council for Science, Engineering & Manufacturing Technologies
SET	Science, Engineering and Technology
SFC	Scottish Funding Council
SIC	Standard Industrial Classification
SMEs	Small and Medium-sized Enterprises
SOC	Standard Occupational Classification
SSC	Sector Skills Council
SSDA	Sector Skill Development Agency
STEM	Science, Technology, Engineering and Mathematics
THES	Times Higher Education Supplement
TRAC	Transparent Approach to Costing
UCAS	Universities and Colleges Admissions Service
UUK	Universities UK

UK higher education qualifications

First/undergraduate degree A first degree normally takes three years full-time study (four years in Scotland). Prerequisites for entry are usually A-levels or equivalent qualifications. Examples of first degrees include Bachelor of Science (BSc) and Bachelor of Arts (BA) qualifications.

Stand-alone masters A stand-alone masters normally takes one year of full-time study. Prerequisites for entry are usually an undergraduate degree or equivalent. Examples of stand-alone masters include Master of Science (MSc) and Master of Arts (MA) qualifications. Stand-alone masters can be either taught or research based.

Integrated masters An integrated masters degree normally takes four years full time study. The first three years are equivalent to a three year first degree, while the final fourth year consists of masters-level study. Integrated masters only exist in some science subjects, including physics (MPhys) and mathematics (MMath).

Doctorates (PhDs) Doctorates normally take at least three years of full time study. Prerequisites for entry are an undergraduate degree, additionally some doctorate entrants will hold a masters-level qualification.

Annex 1 Participants in this study

Lead officer

Professor Martin Taylor FRS, Physical Secretary and Vice-President of the Royal Society

Working group chair

Professor Judith AK Howard CBE FRS, Head of Department of Chemistry, University of Durham (chair)

Working group members

Dr Kathy Barrett, Higher Education Careers Adviser, UCL Careers Service (part of The Careers Group)

Professor Amanda Chetwynd, Pro-Vice-Chancellor, Lancaster University

Professor Patrick Dowling CBE FREng FRS, Chair, Royal Society Education Committee

Professor Laurence Eaves CBE FRS, Professor of Physics, University of Nottingham

Professor Alexander Halliday FRS, Head of the Mathematical, Physical and Life Sciences Division and Professor of Geochemistry, University of Oxford

Professor Edgar Jenkins, Emeritus Professor of Science Education Policy, University of Leeds

Mr Geoff Mason, Senior Research Fellow, National Institute of Economic and Social Research

Dr Andy Merritt, Director High Throughput Chemistry, GlaxoSmithKline R&D

Mr Philip Ruffles CBE FREng FRS, Former Director Engineering & Technology, Rolls-Royce

Professor John Spicer, School of Biological Sciences, University of Plymouth

Professor Joan Stringer CBE, Principal & Vice Chancellor, Napier University

Professor John Wood FREng, Principal of the Faculty of Engineering, Imperial College

Implementation group

Lord Rees of Ludlow PRS, President of the Royal Society (Chair)

Sir Tom Blundell FRS, Chair of School of Biological Sciences University of Cambridge

Lord Browne of Madingley FRS, FREng President Royal Academy of Engineering

Dame Ann Dowling DBE FRS, FREng Professor of Mechanical Engineering, University of Cambridge

Professor Judith AK Howard CBE FRS, chair of Royal Society Higher Education Working Group

Sir Tom McKillop FRS, Chairman Royal Bank of Scotland Group Plc

Council Review Group

Sir David Read FRS, Biological Secretary and Vice-President of the Royal Society (chair)

Professor Dianne Edwards FRS

Professor Nancy Rothwell FRS

Professor Adrian Smith FRS

Secretariat

Ms Nicola Berkley (from January 2007)

Mr David Brodie (November 2006–July 2007)

Dr Peter Collins

Ms Alice Raine (née Sharp Pierson)

Ms Sarah Revell (until March 2007)

Dr Keith Root (until January 2007)

Annex 2 Responses to the call for evidence

We are grateful to the following organisations, which responded to our call for evidence.

Association of the British Pharmaceutical Industry

Campaign for Science and Engineering

Council for Mathematical Sciences

Engineering Professors' Council

Heads of Departments of Mathematical Sciences in the UK

Institute of Physics

London Metropolitan University

Maths, Stats & OR network

The R&D Society

Royal Academy of Engineering

Royal Society of Chemistry

Society for General Microbiology

Wellcome Trust

We also collected evidence from the Society's Fellows and research fellows via Discussion Day 2006.

Evidence is available on the Royal Society website: www.royalsociety.org

Annex 3 Additional data

Figure A1 Masters obtained by UK-domiciled students by subject area, 2004/05 (total masters obtained 49,470) (HESA data).

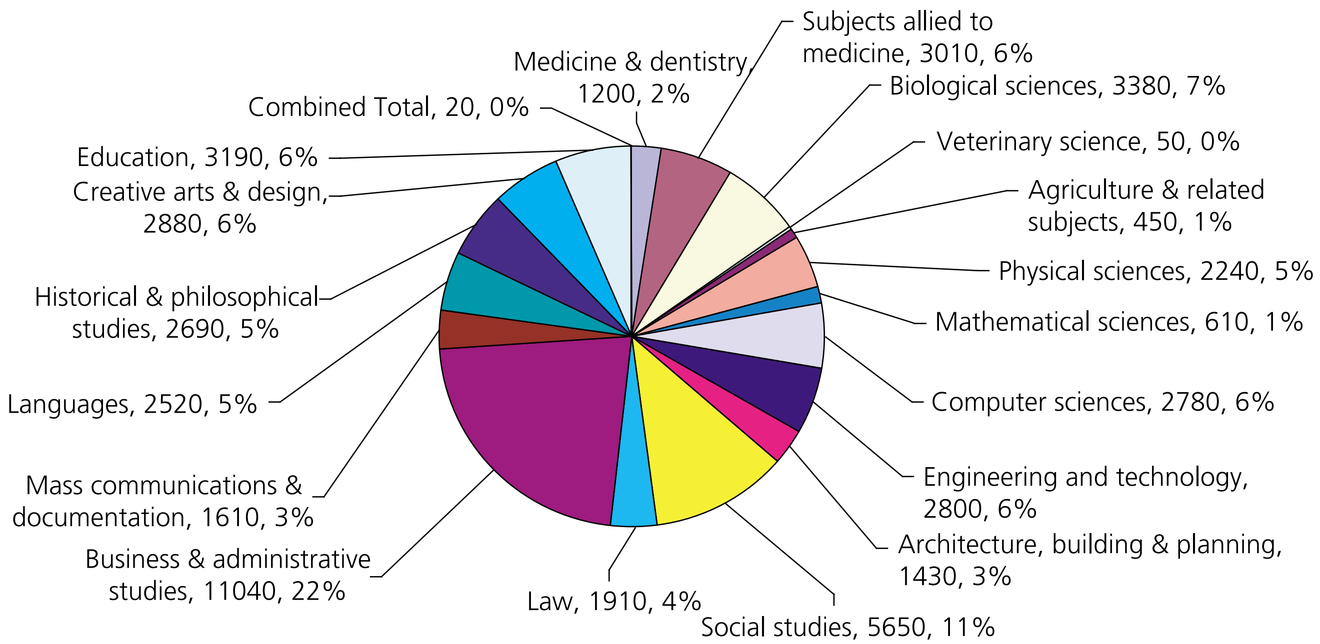


Figure A2 Doctorates obtained by UK-domiciled students by subject area, 2004/05 (total doctorates obtained 9,640) (HESA data).

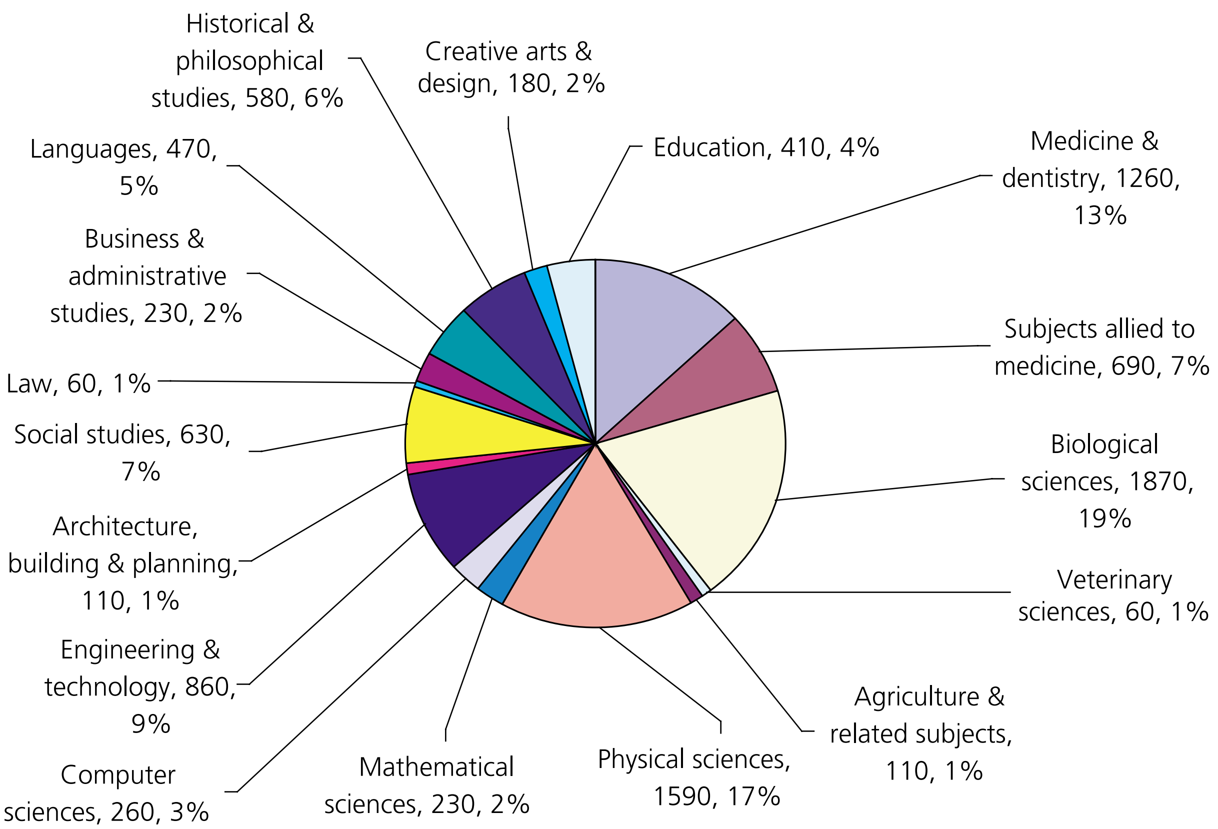


Figure A3 Masters obtained in the biological sciences (by subject) by UK-domiciled students, 1994/95 to 2004/05 (HESA data).

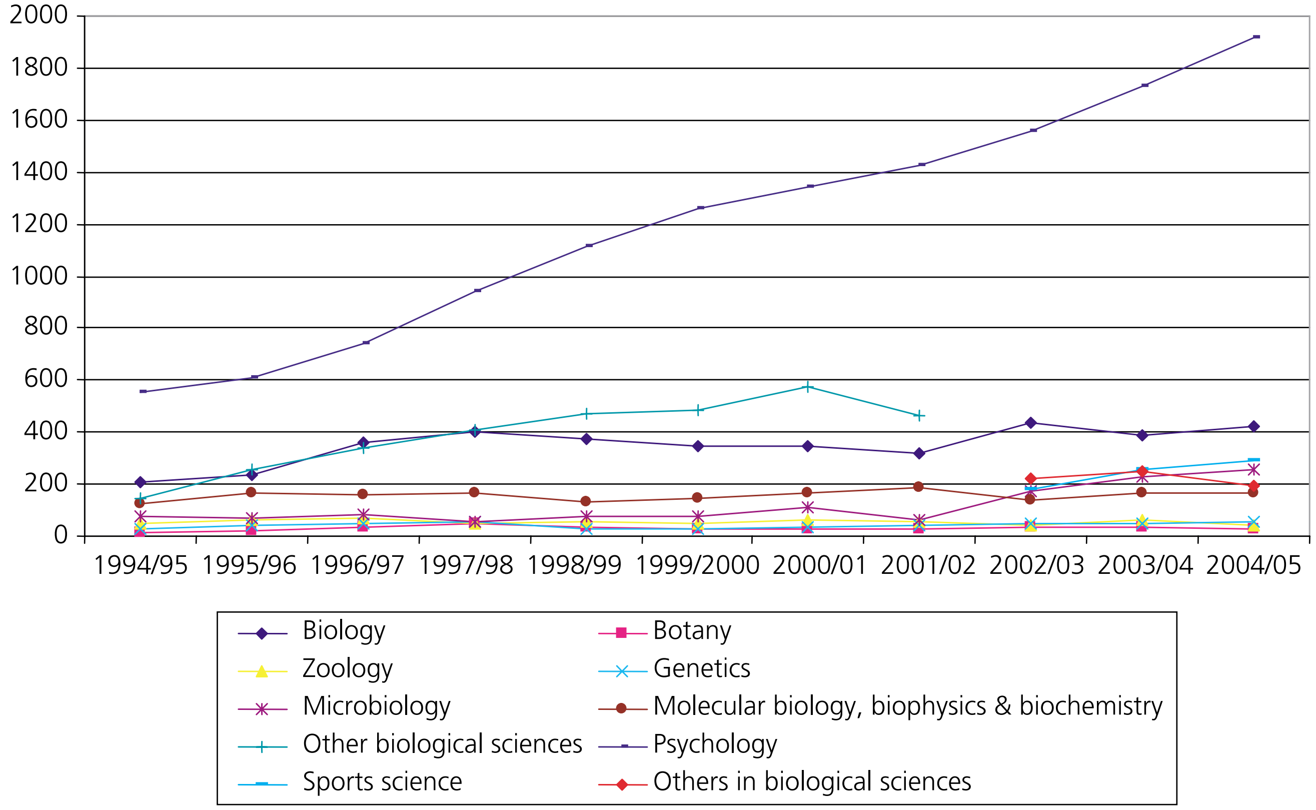


Figure A4 Doctorates obtained in the biological sciences (by subject) by UK-domiciled students, 1994/95 to 2004/05 (HESA data).

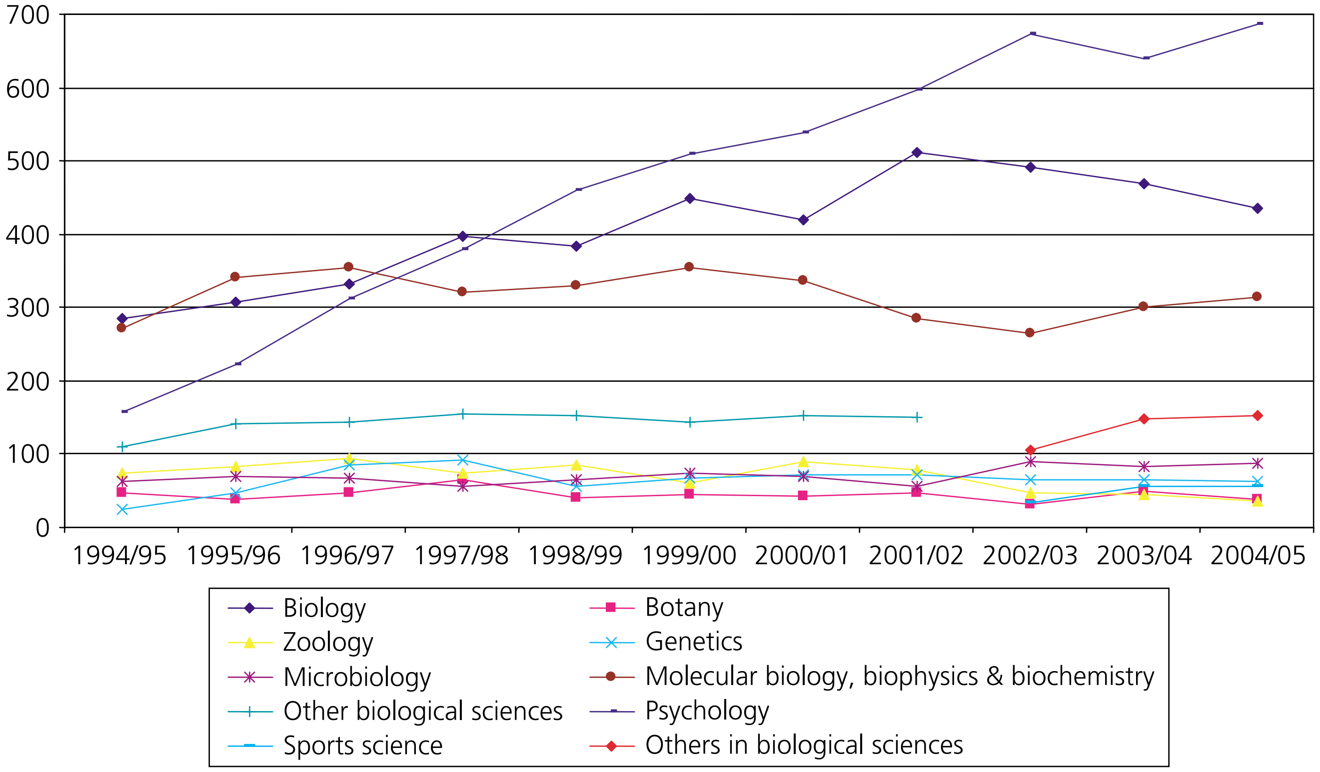


Figure A5 Masters obtained in the physical sciences and mathematics (by subject) by UK-domiciled students, 1994/95 to 2004/05 (HESA data).

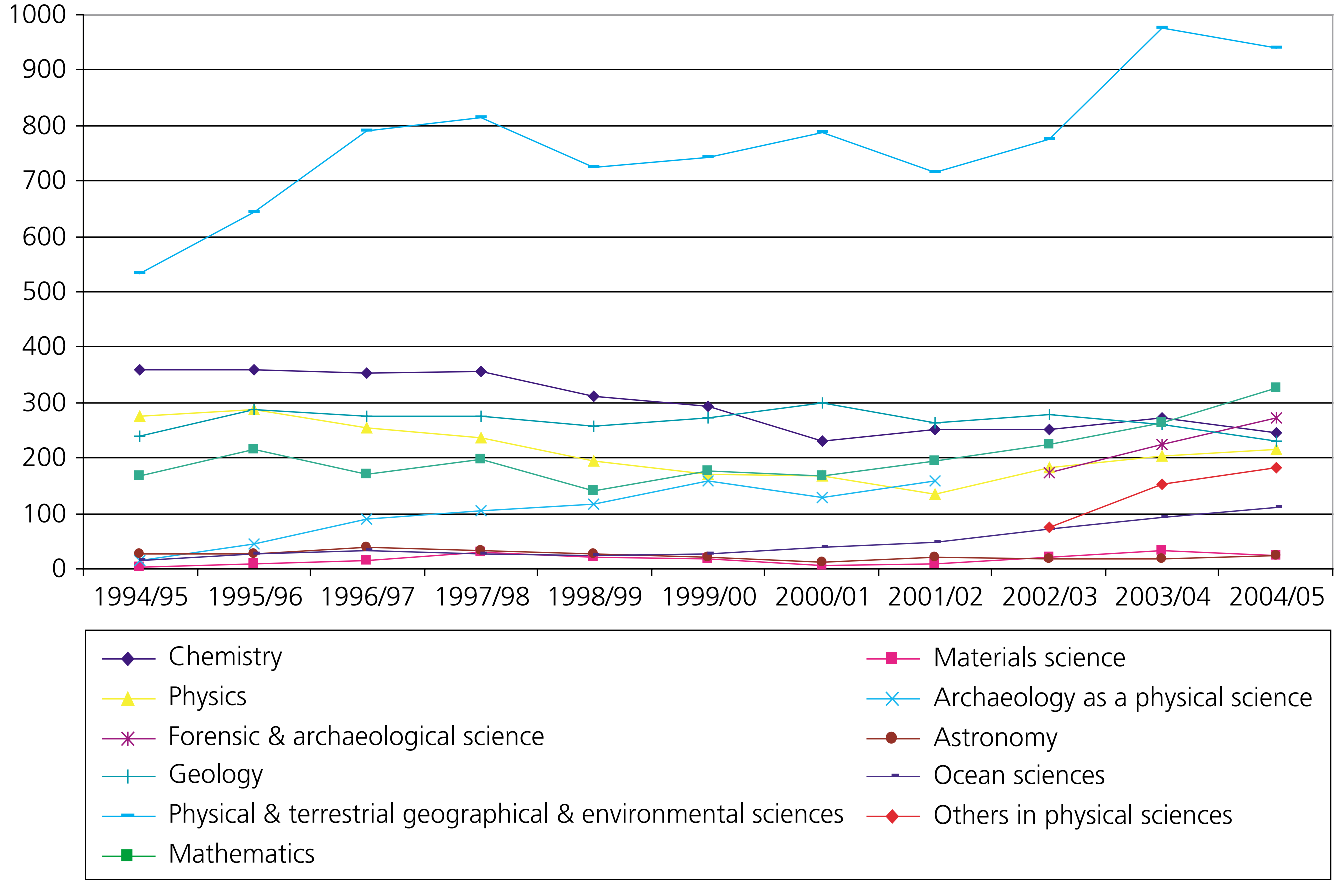


Figure A6 Doctorates obtained in the physical sciences and mathematics (by subject) by UK-domiciled students, 1994/95 to 2004/05 (HESA data).

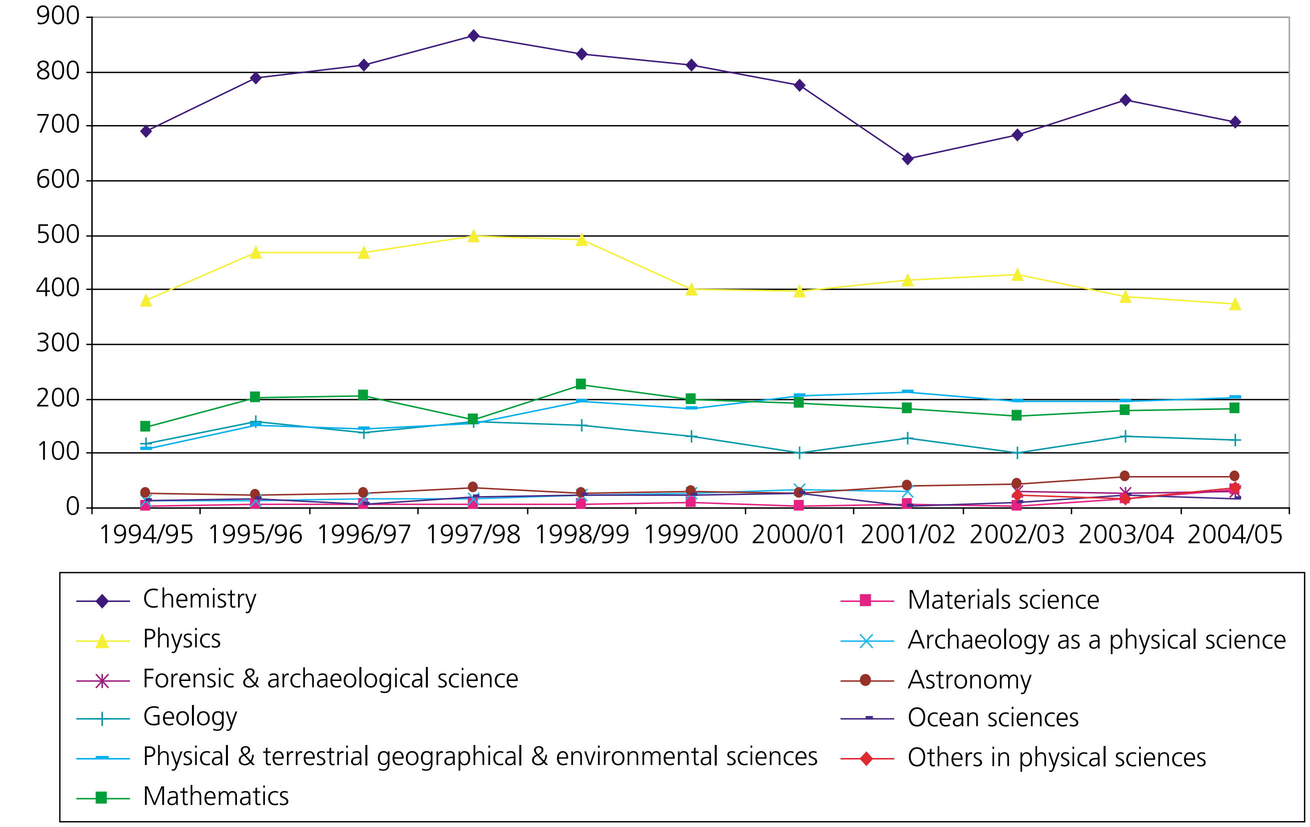


Figure A7 Masters obtained in engineering and computer science (by subject) by UK-domiciled students, 1994/95 to 2004/05 (HESA data).

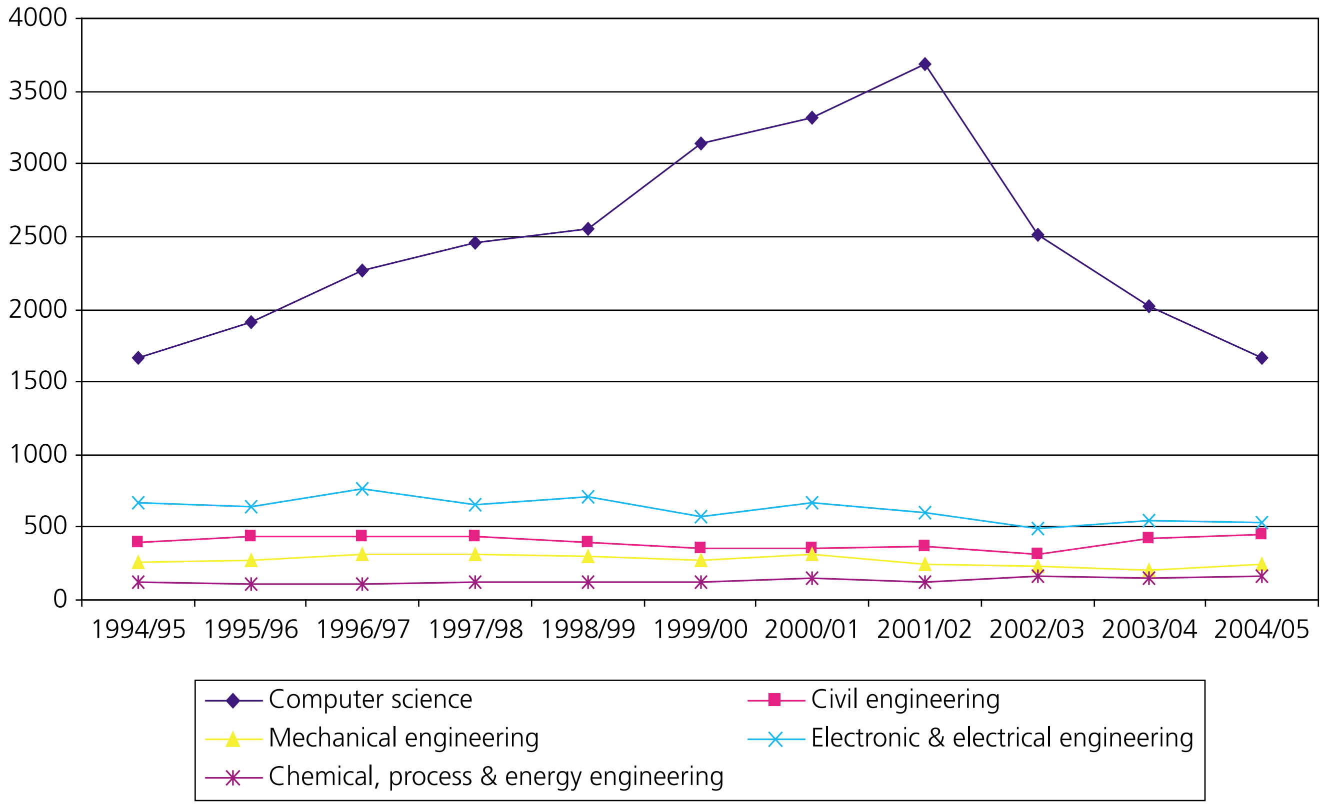


Figure A8 Doctorates obtained in engineering and computer science (by subject) by UK-domiciled students, 1994/95 to 2004/05 (HESA data).

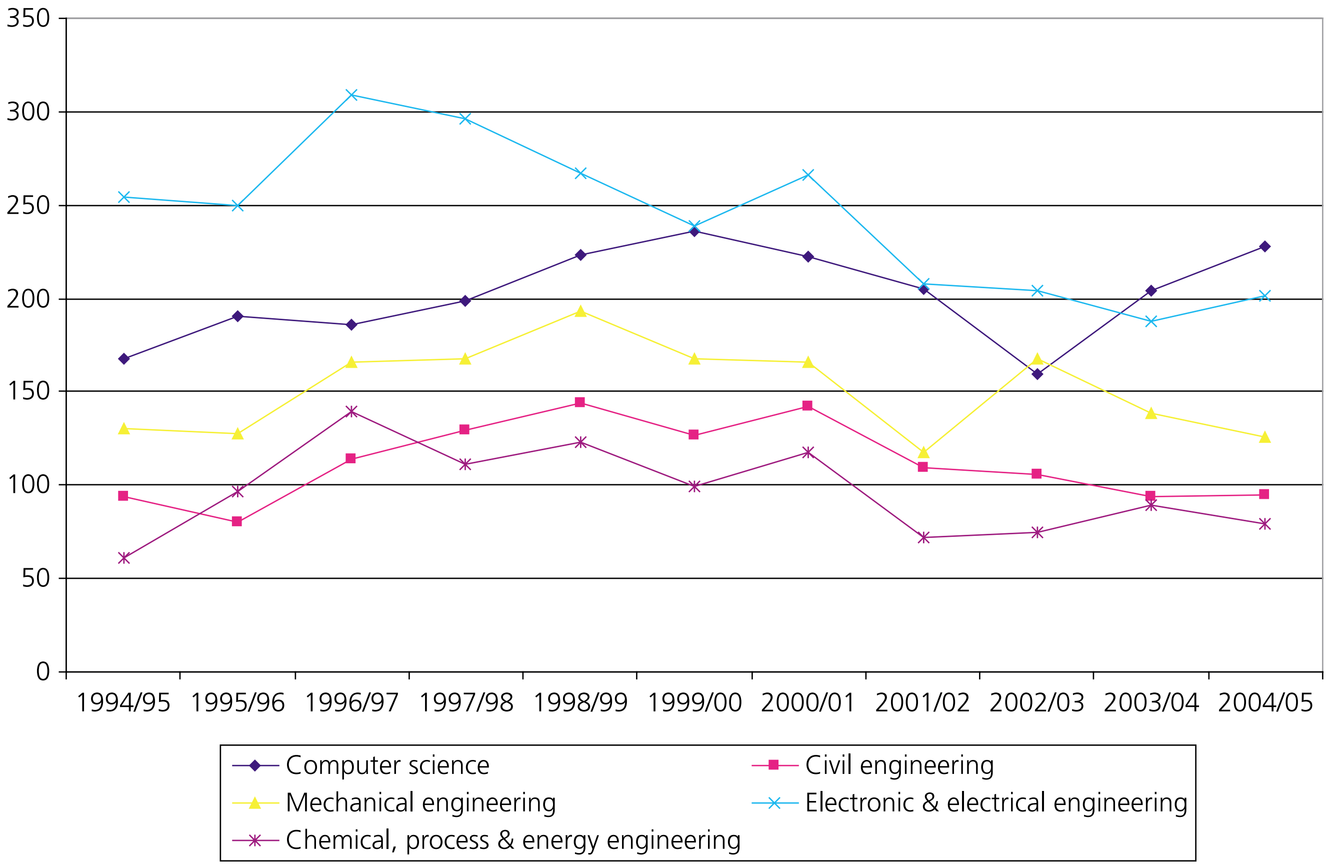
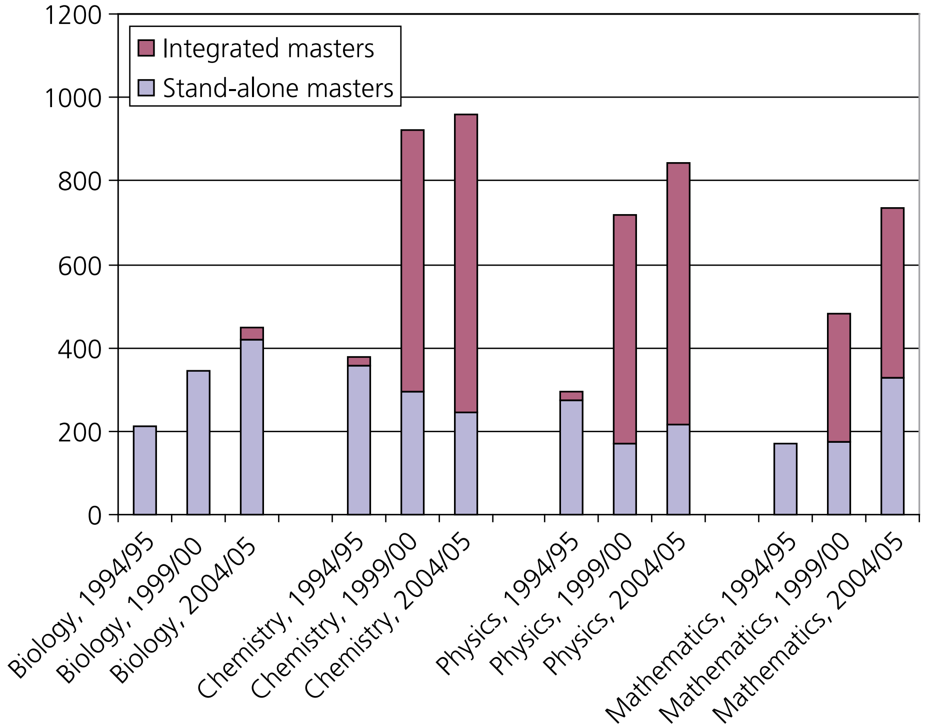


Figure A9 Masters awarded in selected science subjects, by masters type (HESA data).



Annex 4 Details of broader science courses

Natural sciences

In the academic year 2007/08, honours degrees in 'Natural Sciences' were being offered by at least 15 HEIs across the UK (UCAS 2007).

The common element running through such courses is that they offer students the opportunity to study more than one science subject at HE level, typically – but not always – specialising in one or two 'major' subjects towards the end of the programme.

However, there are some features that apply to some courses, but not necessarily all of them:

- **Integration** – Some programmes involve study of the different sciences in an integrated way, perhaps achieving this through topic-based study, the study of topics at the interface, or a cross-cutting project or dissertation, while others simply allow students to select modules from different science departments.
- **Entry requirements** – Several HEIs require that entrants have at least three As at A-level, while others are less demanding.
- **Academic demands** – Some make high demands of their students, so that in at least one case the university claims that it provides the benefits of a multidisciplinary course coupled with reaching a full single disciplinary standard in the chosen major subject (University of Cambridge 2007)
- **Routes into traditional core sciences** – Generally, graduates of Natural Sciences will be able to transfer to the study of a single science at some point, although the arrangements vary between HEIs.
- **Industrial placements** are offered in some cases.
- The **opportunity to study abroad** may also be included.
- There may be the option to study **non-science subjects** too.

Course prospectuses emphasise the benefits of studying across a range of sciences, including the opportunity not to specialise too early and to study subjects on the boundaries of different disciplines. They also indicate a wide range of career opportunities for graduates including scientific research and advice, and roles in management and manufacturing, teaching, law, broadcasting, consultancy, and finance.

Given the variety between the different programmes, in both content and structure, it is difficult to generalise about Natural Sciences. At certain HEIs the course is highly challenging, and graduates have often gone on to very successful science careers. However their success may be attributable to a variety of factors including the academic strength and drive of the individual students, the ability of the HEI to select only the very best applicants, and its teaching and other resources.

Liberal Studies in Science

In 1966 the University of Manchester launched an honours programme in Liberal Studies in Science, which was delivered for some 20 years until its closure in the mid-1980s.

The programme's founders – who were eminent academics from science and economics – had observed that UK universities were producing more science graduates than could be employed in the traditional 'science jobs' available, and also that there was a wider need for 'a new type of science graduate on the one hand, and of a desire for a new type of scientific education from students on the other. Our intention is to produce a new breed of high-calibre generalists from the science side. To do this, we are providing an education which is scientifically oriented but is designed for young men and women who do not intend to become professional practising scientists – not because they are not 'good enough' to make the grade in research but because their interests lie in broader spheres.' (Jevons 1967)

(*Box continues*)

(*Box continued*)

During their three years on the programme, students divided their time between '*doing* science and *thinking about* science'. They took courses in a range of traditional science subjects, together with others in the history and philosophy of science, economics and economic history, innovation and technological change, and sociological and political perspectives on science and technology. The programme was designed to be demanding; on top of attendance at lectures and laboratories, students were required to write an essay every week which reached across discipline boundaries – and the programme has been likened to the 'Greats' at Oxbridge.

The aspiration was that liberal studies in science graduates would enter careers where they could interpret scientific issues in a society where the understanding of such matters was increasingly important. Professor Fred Jevons, who headed the Department for its first decade, reported that of the 49 students graduating up to 1971, 17 went into managerial roles in industry, 11 went onto postgraduate study, 9 were accepted onto teacher training, and others went into a range of posts including hospital and university administration, science journalism, social work and accountancy. Other graduates went into the Civil Service and the voluntary sector.

Professor Michael Gibbons, who succeeded Professor Jevons, kindly gave oral evidence to our Working Group. He confirmed that the programme was initially able to attract 13–15 entrants each year, with A or B grades in three science A-Levels, and was very highly regarded. He attributed the closure of the course to changes in the HE environment, the emergence of quantitative indicators – with greater attention to staff-student ratios, the number of acceptances relative to total applications, and A-level scores. With tighter budgetary controls, the department could no longer rely upon the free loan of teachers from other departments, and at the same time it faced a decline in the number and quality of student applications. The honours programme was closed, although postgraduate studies continued.

Professor Gibbons observed that the department had experienced two challenges still reported by some promoting inter-disciplinary honours programmes today: how to overcome the firm view of many school teachers and parents that traditional disciplines are a superior avenue for undergraduate study, and the heavy demands that a truly integrated programme places on departmental resources.

Integrated sciences

From Autumn 2007, four English universities are offering a new, physics based, interdisciplinary science degree called *Integrated Sciences*. These are recognised by the Institute of Physics (IoP) under its *Stimulating Physics* programme funded by HEFCE and are being delivered by the Universities of Leicester, London South Bank and East Anglia.

The Leicester programme is largely a continuation of its *i-Science* programme launched in 2004, while the UEA has modified an existing Natural Sciences course. The other two programmes are completely new. The IoP hopes that other HEIs will sign up for the brand in the coming years.

The courses span across a range of core disciplines, and the objectives include:

- Improving the attractiveness of undergraduate physics degrees, especially to those from lower socio-economic groups and non-traditional backgrounds, and 'returners' to education.
- To develop a route into HE physics, facing those living in regions with no provision for undergraduate physics, or who have not taken the right combination of A-levels.
- To develop broadly based science degree courses with graduates having a sufficient grounding in physics to enter the teaching profession or work in a technical capacity in industry or other employment sectors.

The courses may also appeal to those with an interest in science who are not yet ready to choose a specialism. The IoP allows participating HEIs some flexibility in designing their programmes and so there are variations in academic entry requirements, course content, and the extent to which the different sciences are integrated (or taught separately). They also offer different flavours; for example Surrey has excellent links with industry and their students will be offered an industrial placement, East Anglia addresses the paucity of undergraduate physics provision in a large region of the UK, while London South Bank has excellent links under the Widening Participation agenda and also offers a sandwich year in industry or elsewhere.

(*Box continues*)

(*Box continued*)

Leicester offers a road-tested model of how such a course might look after a few years. Since 2004 it has developed a programme of integrated problem-based learning, through the study of several topics each year that draw on several different sciences. For example, the first module examines the science of the pyramids, incorporating some basic archaeology, with some nuclear physics and chemistry in examining radiocarbon dating. It introduces students to geology through examination of the rock, and tackles some observational astronomy and basic mechanics in moving and aligning the stones.

Following the first two years of study, a student should be able to transfer to the start of the second year of a physics degree, and some programmes will permit transfers to biological sciences, chemistry and earth sciences too. Such students may complete their honours degree within four years, or an integrated masters degree in five.

University publicity for the Integrated Sciences degrees promises graduates excellent career prospects and indicates that they may hope to proceed to roles in management, teaching, journalism or other communications, or scientific research. Of the first cohort of six students expecting to graduate from Leicester in the summer of 2007, two were planning to proceed to teacher training, two to post-graduate study, and the others were considering offers of work in web design and environmental management.

General Science degrees

Historically, there have been several General Science degrees and some interesting discussion may be found in N. Thompson's discussion of The History of the Department of Physics in Bristol: 1948 to 1988 (Thompson 1992). This reports some difficulties that are often repeated in relation to interdisciplinary programmes:

'Clearly, all was not well with the General Science degree. Although when awarded with honours – as was usual – it was supposed to have parity of esteem with Honours degrees in particular subjects, this was not in fact the case. Outside the University, and particularly in schools, it was frequently thought of as a pass i.e. non-honours qualification ... Inside the University, it was manifestly regarded as second-best.'

Other reports indicate similar difficulties with standards and esteem:

- The University of Glasgow's Faculties of Science General Degree Working Group's minutes of 23 January 2001 http://www.scifac.gla.ac.uk reported that the case had been made for abolishing the BSc General Science degree on the basis that students would be unlikely to be able to meet new more demanding academic requirements at level-3 introduced into the regulations in 2000–01. 'It was noted that most of the 27 students who had graduated last session with a BSc General Science degree would not have been able academically to proceed to level-3 study.'
- A proposal in 2003 to introduce a General Science degree at the University of Edinburgh was abandoned.

Relevant Royal Society policy reports, statements and responses

Sustainable biofuels: prospects and challenges
(88 pages, January 2008, 01/08)

Royal Society statement to the IUS Select Committee on the science budget allocations
(1 page, December 2007, 31/07)

The UK's science and mathematics teaching workforce. A 'state of the nation' report.
(108 pages, December 2007, RS1018)

Biodiversity – climate interactions: report of a meeting held at the Royal Society
(66 pages, December 2007, 28/07)

Royal Society response to International Mechanism on Scientific Expertise on Biodiversity (IMoSEB) consultation
(3 pages, December 2007, 27/07)

Royal Society submission to DFID's consultation on its Research Strategy 2008–2013
(12 pages, September 2007, 25/07)

Strategy options for the UK's separated plutonium
(36 pages, September 2007, 24/07)

A SCORE submission to the House of Commons Education and Skills Committee inquiry into testing and assessment
(4 pages, June 2007)

Royal Society response to the UK Climate Change Bill consultation
(7 pages, June 2007, 18/07)

Joint science academies' statement: the promotion and protection of innovation
(2 pages, May 2007, 15/07)

Joint science academies' statement: Sustainability, energy efficiency and climate protection
(2 pages, May 2007, 14/07)

Submission to the House of Commons Science and Technology Committee Inquiry on the Research Councils
(7 pages, May 2007, 12/07)

SCORE response to the House of Lords Science and Technology Committee report on science in schools
(11 pages, May 2007)

A report from the National Education Research Foundation, commissioned by the Royal Society, on 'Increasing capacity in STEM education research – a study exploring the potential for a fellowship programme'
(70 pages, April 2007).

Submission to the STEM Taskforce Science and Society enquiry
(6 pages, February 2007, 06/07)

Response to RCUK consultation on the efficiency and effectiveness of peer review
(8 pages, February 2007, 04/07)

The future sustainability of the higher education sector: purpose, funding and structures
(15 pages, December 2006, 41/06)

Submission to the House of Commons Education and Skills Committee inquiry on the Bologna Process
(5 pages, December 2006, 40/06)

Royal Society response to the Gowers Review of Intellectual Property
(6 pages, November 2006, 27/06)

A degree of concern? First degrees in science, technology and mathematics
(88 pages, October 2006, 31/06)

Response to the Government's *Next steps* consultation on maximising the impact of science on innovation
(15 pages, October 2006, 21/06)

These reports can be found on the Royal Society's website (royalsociety.org)

Further copies of these reports can be obtained from:

Science Policy Section, The Royal Society,
6–9 Carlton House Terrace, London SW1Y 5AG

For further information:
Science Policy
The Royal Society
6–9 Carlton House Terrace
London SW1Y 5AG
tel +44 (0)20 7451 2500
fax +44 (0)20 7451 2692
email science.policy@royalsociety.org
web royalsociety.org

The Royal Society

The Royal Society is a Fellowship of more than 1300 outstanding individuals from all areas of science, mathematics, engineering and medicine, who form a global scientific network of the highest calibre. The Fellowship is supported by over 100 permanent staff with responsibility for the day-to-day management of the Society and its activities. The Society encourages public debate on key issues involving science, engineering and medicine, and the use of high quality scientific advice in policy-making. We are committed to delivering the best independent expert advice, drawing upon the experience of the Society's Fellows and Foreign Members, the wider scientific community and relevant stakeholders

As we prepare for our 350th anniversary in 2010, we are working to achieve five strategic priorities:

- **Invest** in future scientific leaders and in innovation
- **Influence** policymaking with the best scientific advice
- **Invigorate** science and mathematics education
- **Increase** access to the best science internationally
- **Inspire** an interest in the joy, wonder and excitement of scientific discovery

ISBN 978-0-85403-673-8
Issued January 2008 RS1068

Founded in 1660, the Royal Society is the independent scientific academy of the UK, dedicated to promoting excellence in science

Registered Charity No 207043