THE ROYAL SOCIETY

A degree of concern?
UK first degrees in science,
technology and mathematics

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Contents

Summary

This report sets out the background information and initial findings of a project to explore the widespread concerns over the supply of skilled people needed to maintain the UK as a leading knowledge economy. Phase I of the project concentrates on science, technology and mathematics (STM) first degree courses in the UK. This report is designed to underpin a wider study of the fitness for purpose of UK STM higher education (HE) into the middle of the next decade and beyond, and includes a wide range of data on STM A-levels, STM first degree courses and the first destination of STM graduates.

This report, based on a detailed analysis of relevant statistics, draws attention to:

- the need to place UK developments in an European and global context, including the contributions that both students and staff from outside the UK make to UK HE;

- the importance of a high degree of flexibility throughout the education system;

- the importance of looking in detail at individual disciplines, not just broader subject groupings;

- the mostly downward trends in numbers taking STM A-levels and undergraduate degrees;

- our reanalysis of the Higher Education Statistics Agency (HESA) data, which has shown that the recent apparent large rise in first degree graduates in mathematics and biology is essentially a misleading reflection of changes to the way students on joint courses are attributed to subjects and how subjects are classified;

- the lack of fluency in basic mathematical skills shown by many entrants to undergraduate courses;

- the significant premium placed on STM graduate skills by employers.

Our analysis has identified several issues concerning first degree STM courses including: the need to take account of changes to the 14–19 curriculum; the balance between depth and breadth in first degree courses; the place of four-year integrated masters courses in some STM disciplines; and the need to be closely involved with and influence related developments in Europe including the Bologna process, to ensure that the UK HE system remains world class into the next decade and beyond. Further work will be required to provide a more comprehensive look at HE up to PhD level; we shall be taking this forward within phase II of this project.

Although any attempt at estimating the total number of graduates with particular skills is fraught with obvious difficulties, we can be confident that the development of the UK as a major knowledge-based economy will require:

- an excellent and vibrant university research base, with a wide spread of subjects;

- a sustained supply of STM 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.

The post-16/HE interface

A-levels and, for Scottish school students, Highers and Advanced Highers, are currently the most common route into STM subjects at HE level. We have identified some concerns about trends in the number of students with suitable qualifications for first degree STM courses and the potential for mismatch between the prior knowledge expected from entrants and the actual knowledge of school- and college-leavers.

Trends in A-level entries and combinations of subjects

The number of A-level entries in the UK grew by 10% between 1992 and 2006, from 731,000 to 806,000. Within this context of increasing overall numbers there have been decreases of 6% in the number of entries to chemistry (from 43,000 to 40,000); 34% in physics (from 41,000 to 27,000); and 13% in mathematics and further mathematics (from 72,000 to 63,000), with the decrease occurring mainly in mathematics rather than further mathematics. Entries to biology A-level have fluctuated but increased 13% overall during this period (49,000 to 55,000). Entries to science and mathematics Highers have fallen over the same period, although the fall in mathematics appears less marked than for A-levels.

There are two particular concerns about the potential pool of first degree undergraduates.

- Since entry to medicine, dentistry and veterinary sciences courses is highly competitive, often requiring three A-grades at A-level, these subjects take a high proportion of the students achieving the top grade in A-level/Advanced Higher chemistry and biology. Medical school places have been expanding rapidly – up 70% between 1997 and 2004 – during a period when numbers of entrants to chemistry A-levels have decreased. The combination of these two trends puts real pressure on the pool of good students who could take first degrees in chemistry and biology.

- The number of students taking A-level mathematics is a limiting factor for any increase in the physical sciences and engineering at first degree level.

Students are studying an increasingly diverse range of subject combinations at AS and A-level. Traditional three- and four-subject combinations of science and maths A-levels have fallen substantially between 2001 and 2003. Although the increased breadth of knowledge that stems from studying more subjects post-16 is valuable, for many first degree STM courses particular combinations of A-level subjects remain important. Students aiming for particular courses in HE must therefore have access to appropriate advice about the implications of their choices of A-levels for entry to those courses.

Bridging the mathematics gap: 16–19 to HE

We are concerned about the gap between school or college level study and HE. The mismatch between students' mathematical skills when they enter HE and the demands of STM first degrees appears to be a particularly acute problem. There are two main issues:

- lack of fluency in basic mathematical skills such as basic algebra and the properties of logarithmic, exponential and trigonometric functions; and

- the fact that A-level syllabuses now exclude topics relevant to certain first degree courses that were previously covered.

Of these, the first is of fundamental importance and requires urgent investigation because, even if treated with special courses in the first year in HE, it severely reduces the confidence and motivation of students over the theoretical parts of the undergraduate curriculum in a wide range of subjects. It is also clear that any action taken to improve the basic mathematical or other skills of new undergraduates takes time that would otherwise have been spent on other parts of the first degree curriculum.

The second issue could become an increasing problem if the 14–19 curriculum is broadened, and needs to be accommodated by the HE curriculum adapting to reflect changes in the 14–19 curriculum. In parallel with this, it is important for the HE community to be clear about the skills, knowledge and experience it seeks in new undergraduates and to continue to be involved, alongside other stakeholders, in shaping the future development of 14–19 education. The Royal Society, with the Advisory Committee on Mathematics Education (ACME), is currently engaging with the Qualifications and Curriculum Agency and science and mathematics education stakeholders, including those from HE and employment, on the ongoing development of new 14–19 curricula and qualifications that will suit the learning needs of young people.

First degrees: students and courses

Consistent data on graduate numbers

Trends in undergraduate participation in STM subjects are complicated; there are no simple headlines. Increasing overall participation in HE, year-on-year fluctuations in student numbers, changes in subject classifications and student categorisation, and the need to look at the trends in individual subjects and not just subject categories, all add to the complexity of the situation.

Most analyses of trends in student and graduate numbers are based on data published by HESA in its annual *Students in HE institutions* volumes from 1994 onwards. Several factors make comparison of the data published by HESA difficult. In particular, there were major changes to the way in which students were counted and classified from 2002/03 onwards.

The Society and the Office of Science and Innovation jointly commissioned HESA to produce data on a consistent basis for the whole period 1994/95 to 2004/05, to offset in particular the discontinuities introduced in 2002/03. From these new data, it is clear that the apparent large rise in student numbers in mathematics and to a lesser extent biology is actually just a consequence of the change in the way that HESA has classified students on dual honours and education (initial teacher training) courses since 2002/03.

STM first degrees within the first degree sector

An increasing proportion of all first degrees are being awarded in the sciences as broadly interpreted – up from 31% in 1994/95 to 37% in 2004/05. Much of this increase is attributable to the categories of computer science (up from 3.7% of all degrees in 1994/95 to 6.3% in 2004/05, but now decreasing) and subjects allied to medicine (up from 4.9% to 9.8%).

There has also been marked growth in biological sciences (5.7% to 9.5%), but, within this, psychology increased from 33% to 47% of the subject category and sports science from under 10% to 19%. Indeed, biology students now account for only 17% of the biological sciences category, down from 31% in 1994/95. Similarly, the drop in the physical sciences category from 6.2% to 4.4% of all first degrees has been accompanied by a drop in chemistry from 29% to 21% of the subject category and an increase in forensic & archaeological science from 2% to 8%. These examples highlight the importance of looking both at the broad subject categories and in more detail at individual disciplines. They also illustrate the changing nature of student choices at undergraduate level.

International dimension

The total number of first degrees awarded to UK-domiciled students grew from 220,000 in 1994/95 to 270,000 in 2004/05, an increase of 23%. However, the student body is becoming increasingly internationalised, and numbers of students domiciled outside the UK, and especially outside the European Union (EU), are increasing even more rapidly. Of the 238,000 first degree graduates in all subjects in 1994/95, 92.5% were UK-domiciled, 3.1% were domiciled elsewhere in the EU and 4.4% were of non-EU domicile. In 2004/05, there were 306,000 first degree graduates, with 88.2% UK-domiciled, 4.5% domiciled elsewhere in the EU and 7.3% of non-EU domicile. In biology, chemistry, physics and maths, however, the proportion of first degree graduates who are UK-domiciled is higher than these averages.

At postgraduate level, too, the student body is becoming increasingly internationalised. The percentage of masters degrees awarded to UK-domiciled students decreased from 68% in 1994/95 to 48% in 2004/05, and the percentage of PhDs decreased from 67% to 61%, although the absolute numbers of UK-domiciled students continue to increase. These trends are important for the future development of HE and the employment market in the UK.

Within the EU, the Bologna process is working towards developing a coherent European HE space to foster employability and mobility in Europe and to increase the competitiveness of European HE in the world. A key aspect of the process is the harmonisation of European HE systems, including the length of study required for different qualifications – notably at masters level. There is a risk that the UK's minimalist approach to Bologna could cost competitive advantage comapred with other EU Member States, for example in attracting the best students from throughout the EU. The UK should use its current chairmanship (until May 2007) of the Bologna discussions to stimulate HE institutions to become more engaged.

Demand for graduates and the purpose of first degrees

First destinations of STM graduates

In 2003/04, 33% of physics graduates, 34% of chemistry graduates, 24% of mathematics graduates and 23% of biology graduates were participating in full-time further study or training six months after graduation, compared with 15% of engineering & technology graduates and an average of 16% for all graduates. The proportion of STM graduates entering employment within six months of completing their courses remained relatively unchanged between 1994/95 and 2003/04, ranging from about 40% for physics to 70% for computer science. The reworked

HESA data show that fewer first degree STM graduates are entering the 'manufacturing R&D' industrial sector than was thought at the time of the 2002 Roberts report *SET for success*.

These first destination statistics are a snapshot six months after graduation, which has limited value as an indicator of long-term career patterns. We welcome HESA's plans to complement their annual first destination surveys with longitudinal follow-up surveys on a sample basis at three and a half years after graduation.

Demand for STM graduates

The importance of having an adequate supply of skilled scientists for professional functions and for general functions throughout the economy has been mentioned already. So, too, has the difficulty of estimating from these requirements the optimum numbers of students studying STM subjects at A-level and undergraduate level. Rather than seeking detailed quantitative predictions, policy-makers should focus on ensuring that HE courses at all levels are satisfactory as a start to lifelong learning, and that they equip their graduates with the flexibility to change directions as required.

It is important that any changes to the HE system should retain this degree of flexibility both for graduates and employers. It is also important that the quality of STM first degree courses is maintained at the highest possible level both to meet the future requirements of employers and to attract the best students from within and beyond the UK.

What should a first degree prepare students for?

Graduates from STM first degrees enter a wide range of occupations, some of which will directly use the technical knowledge gained through their degrees and some of which will draw mainly on wider skills. Although this report is mainly concerned with STM first degrees as a preparation for a professional STM career, where the chosen discipline should be taken as far as possible within such courses, it is highly desirable that science and mathematics graduates should also enter other areas of the economy. Indeed, STM first degrees are seen by employers as a valuable preparation for a wide range of other careers.

It is widely recognised that there can be tensions between first degrees as specialist training and first degrees as generalist education. First degrees in STM should be able to serve both of these aims, especially because many undergraduates are still uncertain about their future career plans, and many graduates who successfully pursue other careers benefit from the high level of practical, analytical, mathematical and modelling skills that STM first degrees develop. But some undergraduates

might find special 'practical-light' options in the final year of value, where other modules could be taken in place of a project or some of the practical work.

Such changes would have impacts beyond first degree courses. There would be a need to develop routes to postgraduate study, perhaps through specialist masters courses, for those who after taking a more general science course wished to pursue scientific research or a more specialised STM career. There would also be associated implications for the total length of time that such a student would take to reach doctorate level.

Future developments

Our report is intended to provide a reliable foundation for further work on aspects of HE policy and we hope that those concerned about HE from whatever perspective will find it of value. The analysis has highlighted several unresolved issues that demand attention from those concerned with the future of STM in the UK. We will be addressing some of these in a successor project, *Science HE 2015 and beyond*, which will consider whether the overall STM HE provision in the UK will be fit for purpose by the second half of the next decade. Key issues here will include: the nature of the benefits that students acquire from studying an STM subject at HE level; current discipline boundaries and whether a general science first degree option could be appropriate; the increasing number of students who choose to study later in their lives; the financial impact upon students who undertake HE study; the significance of the Bologna process; and the impact on the UK of international flows of students and STM professionals.

1 Introduction

1.1 Background

There have long been concerns that the UK education system may not provide the numbers of skilled people needed for the workforce. Fundamental to our success as a nation, this issue is now acquiring increased urgency with the escalating competitive pressures of globalisation, the emergence of rapidly developing economies and the move in developed countries to establish themselves as 'knowledge-based economies'.

The past few years have seen several important developments in UK higher education (HE), notably the Government's commitment to widen participation, the introduction of new tuition fees from 2006 and several detailed changes to the public funding of teaching and research.

Science and technology have also assumed a greater focus in global economic development. The UK Government's 10-year *Science and innovation investment framework: 2004–2014* (HMT 2004), published in July 2004, put science at the heart of economic progress. This and the European Union's aim for Europe to become the most dynamic knowledge-based economy in the world have implications for the level of expertise that will be required from the future UK and European workforces, which in turn will impact on the national and European education systems.

To respond to these developments, policy-makers in the science and education communities and within government and industry need to develop their understanding of the supply and demand system by which people pass from education to employment and vice versa. An evidence-based approach, which takes into account the many complexities of the system, is vital. This work by the Royal Society was started in order to: develop an overview of the current situation, considering particularly the supply of and demand for graduates from first degree science, technology and mathematics (STM) courses; identify areas where more in-depth work is required; build a solid foundation for the ongoing work of the Society, and others, in this area.

1.2 Conduct of the study

The Royal Society convened a working group (membership in Annex 1) including academics across several scientific disciplines, industry representatives, an economist and a university careers adviser to carry out this study. Having defined the data needs of the project and investigated the available published data sources on HE statistics, we commissioned a reworking of data from the Higher Education Statistics Agency (HESA) to a consistent base. Much of this report is based on our analysis of these data. We have written this report to inform future debate both within and outside the Society. The report has been endorsed by the Council of the Royal Society.

1.3 Overview of the report

Our main concern was to develop a fuller understanding of the supply of and demand for graduates from first degree STM courses. The terms 'supply' and 'demand' can refer to several different things in the literature, and are used differently when referring to the start or end of the HE process. In this report we use them at the end of the HE process: 'supply' referring to the supply of people into the economy and 'demand' to the number and types of jobs available within the economy. As we look at the earlier stage of the supply chain – the start of HE – we use the term 'provision' to describe the availability of courses in the HE sector and 'student choice' to denote the demand from students for these courses.

Although chapter 5 focuses on first degrees, presenting an overview of course provision and an analysis of the new HESA data on student numbers, it is clear that any understanding of the supply of and demand for STM first degree graduates also needs to consider students' earlier education and their subsequent career path. Chapter 4 therefore investigates the post-16/HE interface, considering trends in A-level entries, the potential pool of STM undergraduates and the skills and knowledge that it is important for students to develop at this stage of their education. Chapter 6 uses new HESA data to analyse what students are doing six months after graduation from STM first degrees.

Issues of demand are considered further in chapters 7 and 8. Chapter 7 discusses the economic demand for graduates from STM first degrees. Chapter 8 considers the skills, knowledge and experience that it is desirable for STM graduates to have developed through their undergraduate study. Contextualising our concern with first degrees, chapter 2 provides an overview of the changing global HE environment; and chapter 3 discusses undergraduate HE in the UK, exploring its position within the overall education system, its expansion over recent decades and its funding. Finally, chapter 9 draws together our commentary on STM first degrees and the UK HE environment.

Although our remit was to consider STM first degree courses, in some cases information on related engineering courses provided interesting comparisons. Chapters 4, 5

and 6 therefore include some data on science, technology, engineering and mathematics (STEM) first degree courses.

1.4 Future work: Science HE 2015 and beyond

The initial work undertaken as part of this study has started to provide a better idea of the numbers, skills, knowledge and experience of students joining and leaving the university system at first degree level. Our analysis thus far is presented in this report and is intended to provide a reliable foundation for further work on aspects of HE policy. We have also identified several issues that point to the need to look more comprehensively across the HE system, from first degree to PhD.

We shall be addressing some of these in a successor project, *Science HE 2015 and beyond*, which is considering whether the overall STM HE provision in the UK will be fit for purpose by the second half of the next decade. Key issues here will include: the nature of the benefits that students acquire from studying an STM subject at HE level; current discipline boundaries and whether a general science first degree option could be appropriate; the increasing number of students who choose to study later in their lives; the financial impact upon students who undertake HE study; the significance of the Bologna process; and the impact on the UK of international flows of students and STM professionals.

2 The worldwide educational scene and issues for the UK

This chapter sets out the main drivers of change for the UK HE system, which include economic globalisation and the developing European Union (EU) policies for HE. Section 2.1 considers the overall global scene and section 2.2 developments within Europe. The implications of these global and European changes for UK HE are drawn together in section 2.3.

2.1 The overall global scene

2.1.1 The changing global environment

The UK HE system is still well represented within the top institutions in all credible international HE league tables, where the UK's performance is second only to that of the US (see section 2.1.3). However, the global economy is changing, and the UK must increase its efforts just to maintain its position with respect to competitor nations. The migration of manufacturing jobs to emerging economies is a likely precursor to the migration of design and research capabilities. India, China, and other similar countries are investing in their education systems to produce a well-trained, highly skilled workforce, and the economic climate in such places is inviting to companies looking for suitable locations for their research operations.

The Indian National Council of Applied Economic Research's *India science report* (NCAER 2005) reports that

gross enrolment in HE (undergraduate and postgraduate) rose from 1.26 to 1.78 million in the natural sciences and from 0.40 to 1.07 million in engineering between 1995/96 and 2003/04. Figure 2.1 shows how the US National Science Foundation (NSF 2006) estimates of the number of science and engineering graduates per year from the three major supply continents changed between 1994 and 2002. The number of graduates from Asia (mostly China, Japan and India) is not only far larger than the number of graduates from North America or Europe, but it is also increasing at a greater rate. In 2002, Asia supplied approximately as many science and engineering graduates as Europe and North America combined. Numbers are, of course, not the whole story but it is more difficult to compare the quality of STM HE on this scale of aggregation.

The USA is sufficiently concerned about these challenges to be considering strategies to ensure that its universities, and indeed its entire education system, remain competitive in this fast-moving situation. The US National Academies, responding to Senate concern, produced a report (NAS 2005) detailing 20 specific actions that will work towards the USA retaining its position as a global leader in science and technology. These cover four main themes:

(a)   increasing the supply of science teachers;

(b)   increasing federal research funding;

Figure 2.1 Science and engineering first degree graduates in North and Central America, Europe and Asia, 1994–2002 (NSF 2006).
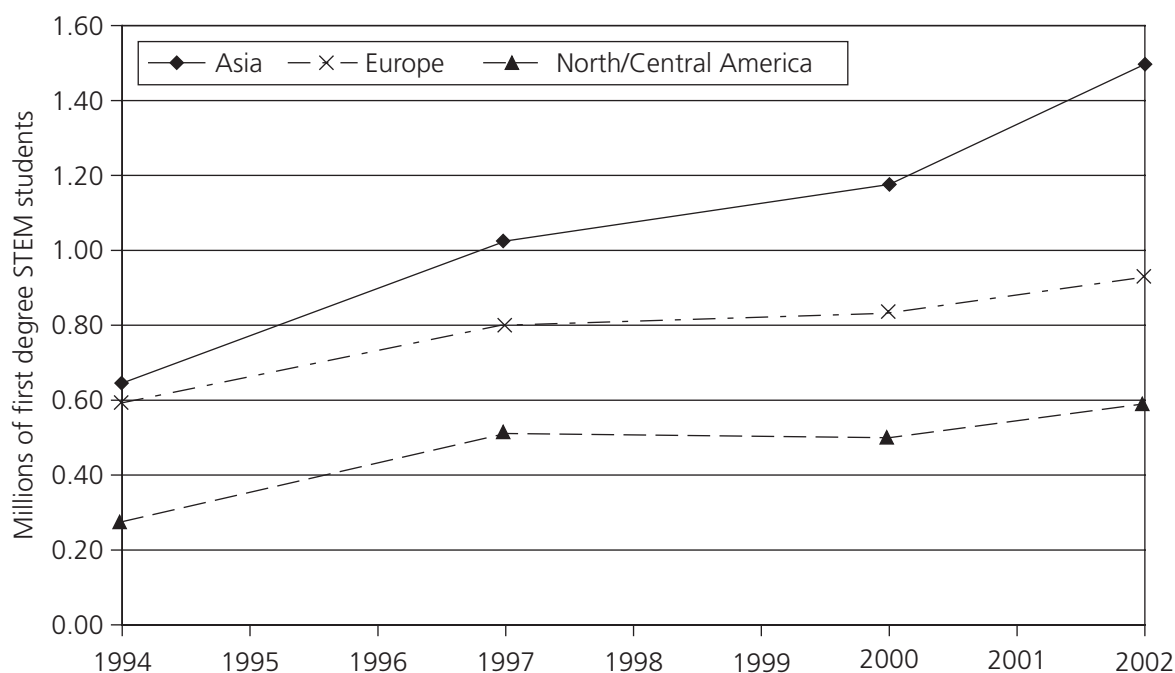
(c)   increasing the supply of science graduates and PhDs; and

(d)   increasing innovation.

Within (c), the National Academies recommend that several undergraduate awards of $20,000 per year are made to students in STEM subjects. They also recommend an increase in the number of graduate fellowships, covering PhD costs; a tax credit to encourage employers to further train their scientists and engineers; and an overhaul of the immigration system for skilled migrants.

2.1.2 Some international comparisons

Comparisons of education between countries are complicated by the differences in the systems, but nevertheless can provide some important general insights. Table 2.1 reports funding of HE institutions as a percentage of gross domestic product (GDP) for several different countries. The first three columns do not include direct student support, which is included in the final column giving total public funding of HE.

In terms of total resources devoted to HE institutions, the figures for the UK, France, Germany and Japan are very similar, but trail significantly behind Sweden and the USA. Further comparisons can be made of student:staff ratios, the total expenditure per HE student, and in an attempt to take account of the different average lengths of HE courses, the cost per student over the average duration of HE (Table 2.2). Unfortunately Organisation for Economic Co-operation and Development (OECD) does not give the US figure for the latter. However, the larger European states are investing less than the USA in all of the categories. This table also reports participation and drop out rates, which appear to put the UK is a relatively good overall position. Both figures are, however, very difficult to compare between different systems, and for drop-out rates the OECD has not up-dated these figures since 2000. Recent changes to the systems in France and Germany may have reduced the drop-out rates in those countries.

2.1.3 International benchmarking and league tables

Comparison of the output and quality of universities is even more difficult and multi-faceted than comparing inputs. Furthermore, most measures are biased towards English language publications and countries where most fundamental research is undertaken at or in close association with universities. The two main international league tables covering both teaching and research functions of the university are Shanghai's Jiao Tong University annual worldwide review, which uses relatively few criteria including Nobel prize winners among faculty and alumni, and that produced by the *Times Higher Educational Supplement* (THES 2006) 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 2006 THES table included eight UK universities in its top 50 universities.

Table 2.1. *Funding of HE in 2002 as percentage of GDP from public and private sources (OECD 2005).*

Country	Funding of HE institutions as a percentage of GDP			Total public funding of HE (including student support)
	Public	Private	Total	
Sweden	1.6	0.2	1.8	2.2
USA	1.2	1.4	2.6	1.4
Germany	1.0	0.1	1.1	1.2
UK	0.8	0.3	1.1	1.1
France	1.0	0.1	1.1	1.0
Japan	0.4	0.6	1.1	0.5
OECD mean	1.0	0.8	1.7	–

Table 2.2. *Comparison of international HE student:staff ratios, funding per student, participation rate and drop-out rates (OECD 2005, including information on website).*

Country	Student:staff ratio 2003	Annual HE funding per student $US, 2002	HE funding per student over average duration of HE $US, 2002	Net entry rate up to age 30, 2003	Drop-out rate 2000 (latest year data available)
UK	18.2	11,822	45,307	48	17%
France	17.6	9,276	43,428	39	41%
Germany	12.5	10,999	58,036	36	30%
Japan	11.0	11,716	45,095	42	6%
Sweden	9.0	15,715	72,408	80	52%
USA	15.2	20,545	Not available	63	Not available

Note: Net entry rate is the probability of a 17 year old entering HE for the first time by the age of 30. It is not directly comparable with the UK's 'initial participation rate', which is discussed in section 3.2.1.

2.2 Developments within Europe

2.2.1 The importance of HE within Europe

The Lisbon 2000 European Council set the objective of Europe becoming 'the most competitive and dynamic knowledge-based economy in the world'. This led to the 2002 Barcelona European Council setting an equally ambitious and more specific quantitative target of increasing the total European research and development expenditure (OECD defined Gross Expenditure on R&D (GERD)) to 3% of GDP by 2010, from its present base of 1.9%. This would, among other things, have significant implications for the number of trained graduates and postgraduates that would be required to sustain this level of research activity in both the public and private sectors. The numbers were considered by a working group chaired by Gago (Gago 2004).

The EU has been pressing for the modernisation of the European HE system, pointing to the enormous potential of the sector, which has over 4,000 institutions, 17 million students and 435,000 researchers. In an announcement on 10 May 2006, the Commission put forward the following proposals:

- boost the proportion of graduates spending at least one semester abroad or in industry;

- allow students to make use of national loans and grants wherever in the EU they decide to study or do research;

- bring procedures for the recognition of academic qualifications in line with those for professional qualifications and make European degrees more easily recognised outside Europe;

- introduce training in intellectual property management, communication, networking, entrepreneurship and team-working as part of a research career;

- refocus courses to allow greater participation at later stages of the life-cycle, thereby addressing the skills needs of Europe's workforce, and ensuring that universities are able to adapt to Europe's ageing population;

- review national student fee and support schemes so that the best students can participate in HE and further research careers whatever their background;

- review systems for funding universities, to be more focused on outputs and give universities more responsibility for their own long-term financial sustainability, particularly in research;

- allow universities greater autonomy and accountability, so that they can respond quickly to

change. This could include revising curricula to adapt to new developments, building closer links between disciplines and focussing on overall research areas domains (eg renewable energy, nanotechnology) rather than disciplines. It could also include more autonomy at individual institution level for choosing teaching and research staff.

These points illustrate the heterogeneous nature of the HE systems within Europe and the wide ranging Commission interest in this area. A key feature in the EU plans is the harmonisation of university bachelor, masters and PhD degrees under the Bologna process, discussed further in section 2.2.2.

European universities have formed several bodies to coordinate activity and to respond to policy developments by the European Community. These include the European University Association: a European-wide association of university rectors. At the grass roots level, certain European universities have formed groupings to exchange ideas on developing teaching courses and students, for example:

- the Coimbra Group: an association of long-established European multidisciplinary universities;

- the League of European Research Universities: a network of 12 European research-intensive universities;

- the Idea League: a partnership of technical universities set up in 1999 by Imperial College London, TU Delft, ETH Zurich, RWTH Aachen and ParisTech.

The formation of these groupings is not intended to hinder in any way bilateral cooperation and collaboration between individuals, research teams or departments within member institutions. On a wider scale there are networks involving universities across the globe such as the World Universities Network, which includes six UK universities, three from elsewhere in Europe, five from the USA, and two from China.

2.2.2 The Bologna process

The Bologna Declaration, signed by European Ministers in June 1999, expressed the goal of developing a European Higher Education Area by 2010, by working towards developing a coherent European HE space to foster employability and mobility in Europe. A key aspect is the harmonisation of HE qualifications within the Community. Historically, the time required to reach PhD-level has varied greatly between countries. In Germany, PhD awardees are often aged 29 or 30, whereas in the UK they are frequently just 24 years old. There is evidence that employers prefer the greater maturity that comes with the increased training time (EPSRC 2002). However, such a lengthy system has cost implications, and puts off many potential students. It also delays

independence for many researchers who are nearing their creative peak.

The Bologna declaration seeks to standardise the time required and the level of qualification awarded at various stages of Higher Education across the EU. The standard structure consists of three years study at undergraduate level, followed by two years to receive a masters and a further three at PhD-level. A masters would be mandatory before a student could progress to a PhD. As discussed further in section 2.3.1, although the UK system is closer to the arrangements than those in some other Member States, there are still some areas of potential conflict. Both France and Germany have made major changes to their university systems to bring them more into line with the Bologna arrangements.

2.2.3 Stimulation of mobility across Europe

The EU introduced the Erasmus (European Community Action Scheme for the Mobility of University Students) educational programme for HE students, teachers and institutions in 1987, with the aim of increasing student mobility within the European Community, subsequently the European Economic Area countries, and now also the Candidate Countries of Bulgaria and Romania. In 1995 it was incorporated into the new Socrates programme, which covers education from school to university to lifelong learning. Socrates–Erasmus can involve student mobility, teacher mobility and curriculum development and is based on cooperation agreements between HE institutions in different participating states. Across the

programme agricultural, natural and medical sciences, mathematics and engineering account for less than 25% of the total number of participants.

The UK has been the largest host nation, but is also the country with the largest imbalance of incoming and outgoing students. The participation of UK nationals in Erasmus in the first few years of the programme until the mid-1990s was comparable to that of France and Germany, involving over 10,000 students, but it has since diminished to about 8,000 students per year, compared with the increased in participation from Germany (20,000) and France (17,000).

The statistics show that countries with a significant element of their HE system taught in English are the main recipients of students, whereas countries that teach primarily in other languages are net senders of students. In the case of UK-domiciled students, there has been an increase in the number spending time abroad as part of their studies, but largely to countries where students are taught in English, the most poplar destinations being the USA and Australia.

2.3 Implications of global and European-wide developments for the UK

The UK is thus in an environment in which the number of competitors has increased, and where these competitors are competing harder. Under many of the normally used criteria, the UK universities are examples of best practice and after the USA are prominent in international league

Figure 2.2. Non-UK members of staff in UK universities 2004/05 (HESA 1997–2006b).
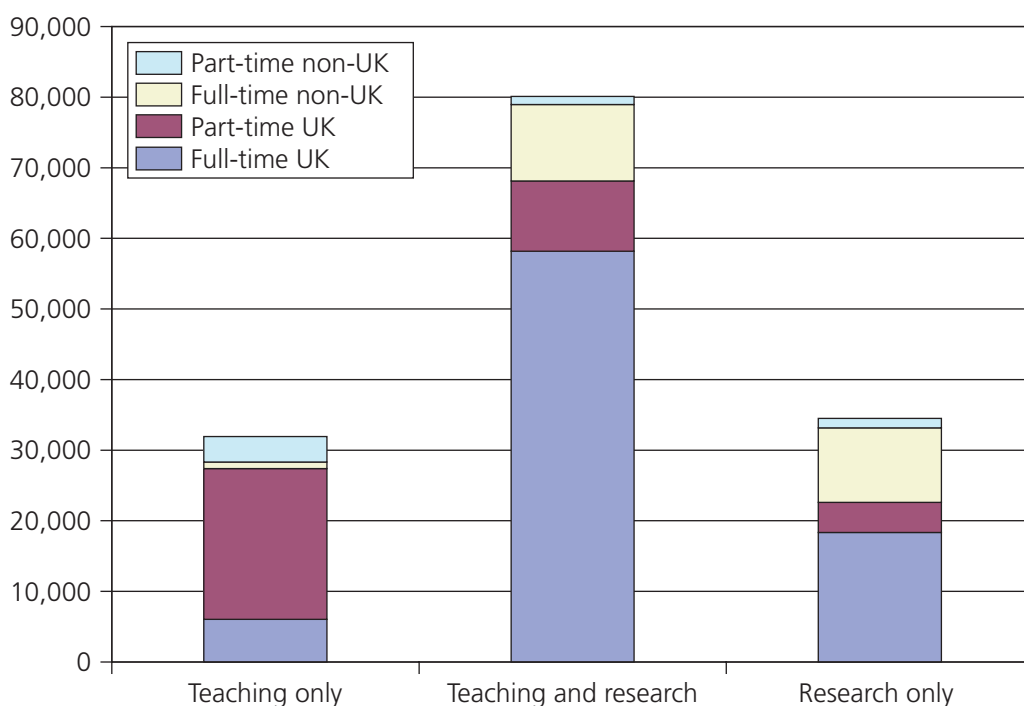
Figure 2.3. First degree, masters and PhD graduates by domicile (UK, other EU and non-EU), 1994/95 and 2004/05 (HESA data).
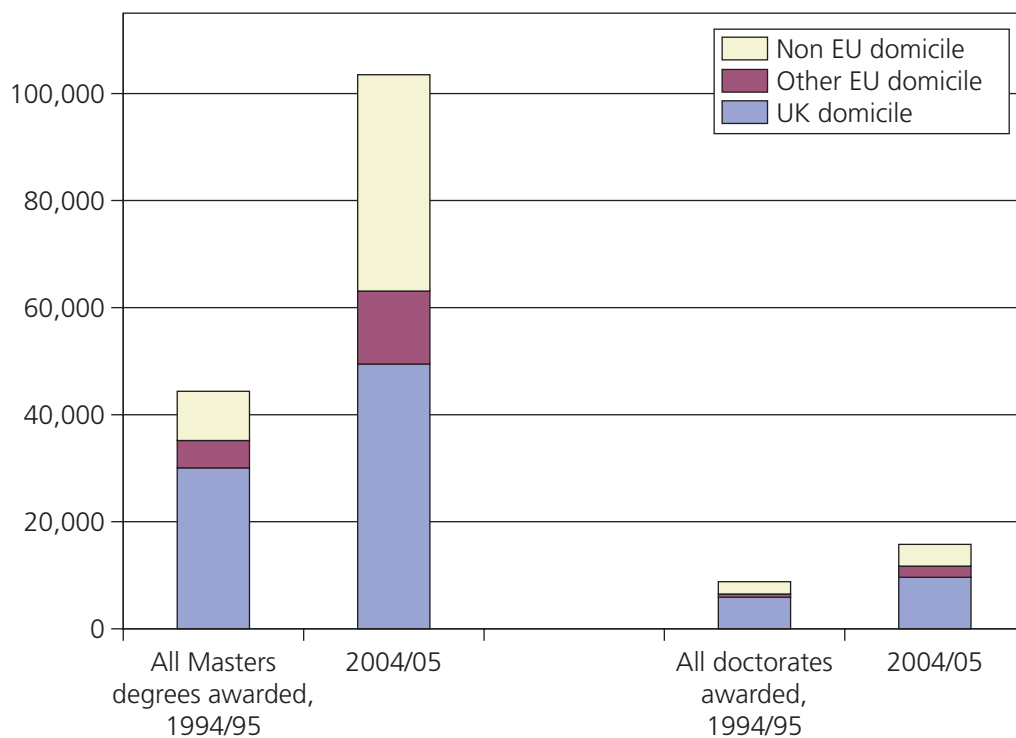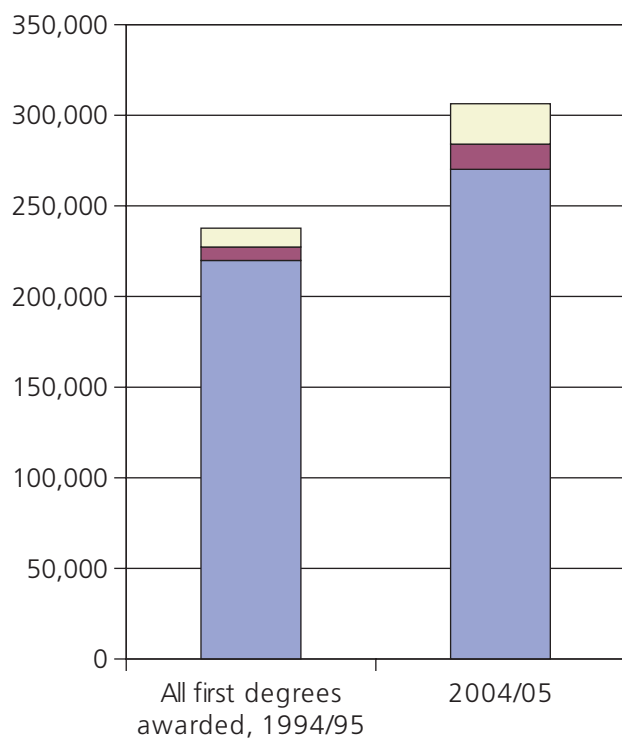
tables, having more high entries than any other member states, and the only entries near the top of these tables apart from the USA. Nevertheless, in view of the developing global situation, the relative position of UK universities is continually under threat, and to continue to thrive as a scientific nation in this environment concerted effort is needed.

2.3.1 The Bologna process

After a slow start, the UK Government has now started to consider seriously the implications of Bologna, where the existing structure, although closer than some countries, does not fit with certain aspects of the UK system, for example:

- The option of an integrated masters course, which takes four years. The implications of Bologna for this degree are considered in a note published by the UUK Europe Unit in consultation with the QAA, the HE Funding Councils and the Standing Conference of Principals, which gives guidance on how such courses could be made Bologna compliant (UUK 2005b).

- One-year masters courses.

- Students being admitted to PhD courses straight from undergraduate courses.

- The increasing trend towards masters funding being linked with PhD funding in a 1 + 3 year structure.

2.3.2 Internationalisation of staff and students

Universities have always attracted scholars and students on a worldwide basis, and as the figures set out in Figures 2.2 and 2.3 show, currently a relatively high proportion of staff and students at UK universities are from overseas. In some institutions, overseas postgraduate students and post doctoral researchers are in the majority. This internationalisation of universities has a major positive impact on quality, and foreign students from outside of the EU make a significant contribution to the overall income of universities.

Figure 2.2 shows that in 2004/05 some 15% of full- and part-time teaching-only and research and teaching staff across all subjects were foreign nationals, whereas almost 35% of research-only staff were foreign nationals. The actual percentage varies with discipline and type of university.

Figure 2.3 illustrates the importance of non-EU students for masters degree courses, with under 50% of the graduates being UK-domiciled.

3 Undergraduate HE in the UK

This chapter discusses undergraduate HE in the UK, exploring its position within the overall education system, its expansion over recent decades and its funding. Section 3.1 explores the position of undergraduate HE within the UK's education and employment systems while section 3.2 details the expansion of HE since the 1960s. Section 3.3 considers HE teaching in terms of the staffing of universities and the development of teaching staff. Finally, section 3.4 explores the funding of HE teaching.

3.1 Undergraduate HE

3.1.1 Domestic issues within UK HE

Quite apart from the issues raised by global and European-wide developments described in chapter 2, there is a range of local issues that have implications for the domestic HE scene including:

- The developments within 14–19 education and the knowledge and skills that students bring with them into HE;

- The expansion of HE participation, which brings with it many other issues including the:
  - introduction of student tuition fees;
  - increased cost to the public purse;
  - decrease in resource per student, previously referred to by Government as an 'efficiency saving';
  - potential decrease in standards of the qualifications with which students start off their undergraduate career, and of those achieving an honours first degree;
  - potential oversupply of graduates;
  - huge increase in some STM subjects – in particular psychology, sports science and computer science;

- The development of four-year integrated masters courses in the physical sciences and engineering, and among other things its effect on the three year BSc;

- The trialling of two-year intensive honours first degrees;

- Some disquiet over the development of modular degrees where credit can be accrued though several independent modules;

- Some, usually anecdotal, complaints that graduates do not have certain basic generic skills that are valuable to future employers.

Many of these issues are explored for STM subjects in chapters 4–8, and their implications are discussed further in chapter 9. The current chapter looks at the overall undergraduate provision within the UK.

3.1.2 The overall education system

The coverage of HE is difficult to define precisely, not least because of its dependence on earlier parts of the educational system – for example, the differences between the education system in Scotland and in other parts of the UK. The problem becomes more complex when international comparisons are attempted. The International Standard Classification of Education (ISCED) splits tertiary education into ISCED 5A and ISCED 5B, with ISCED 6 representing Advanced Research Qualifications. In terms of UK qualifications, ISCED 5A equates roughly with first degrees and ISCED 5B with Higher National Certificate and Higher National Diploma courses (HNC/HND) and Foundation Degrees.

Undergraduate HE covers post A-level HE including first degrees, and HND/HNCs and Foundation Degrees, some of which may be undertaken at FE colleges (HE in FE). The supply of undergraduates through to the economy is shown schematically in Figure 3.1, where the shaded box represents HE provision up to first degree level. The 'further study' box includes higher degrees and shorter postgraduate courses, not all of which result in a formal qualification.

This diagram illustrates the key position of undergraduate education, and the significant degree of flexibility in the system. There is clearly a range of options open to graduates with the appropriate skills if the opportunities within one area of employment are reduced. Similarly, there is significant scope for employers to increase the attractiveness of their vacancies both to new graduates and to recent graduates who have entered other areas of employment. Additionally, there is scope for graduates to refresh or build on their knowledge and skills or to change field through further full-time or part-time study, thus opening up new career paths.

It is also recognised that the graduate labour market is very different now to that of ten to fifteen years ago (DfES 2005). Access to employment opportunities has been affected by the expansion of HE, and the impact of restructuring and new technology, particularly information and computer technology (ICT), has affected the skills required by employers and the very nature of many jobs. Graduates do a much wider range of jobs than in the past and there is enormous diversity in the jobs, the financial returns and the intrinsic satisfaction that graduate jobs offer.

Figure 3.1. The interdependence of the education and employment systems, from school through to employment.
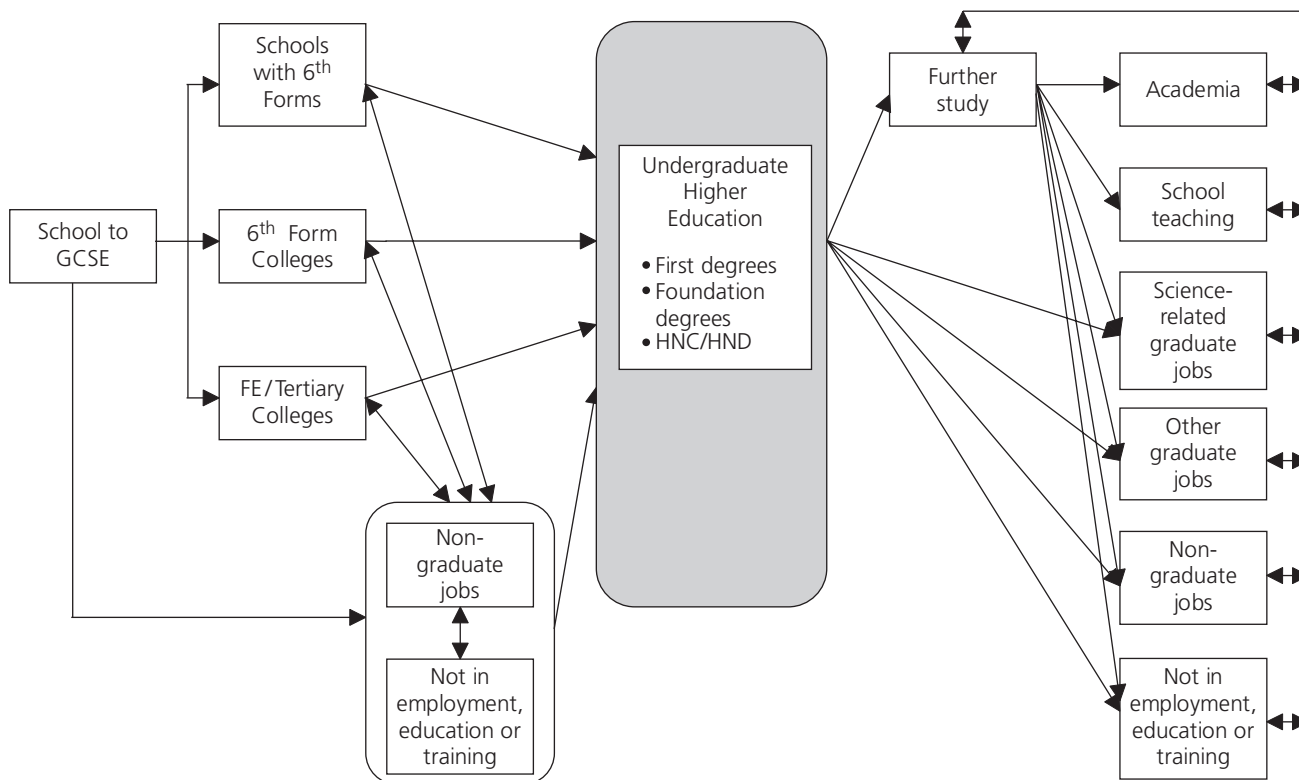
3.1.3 Undergraduate HE

The Higher Education Statistics Agency (HESA) and others distinguish between first degrees and other undergraduate qualifications, equating to the International Standard Classification of Education (ISCED) 5A and 5B respectively.

First degrees

First degree courses are those leading to the award of a bachelors or integrated masters degrees, and in England, Wales and Northern Ireland are typically equivalent to three or four years of full-time study. Recently, the Government has announced that five institutions (Staffordshire University, Derby University, Leeds Metropolitan University, University of Northampton and The Medway Partnership in Kent) will trial two-year fast-track degrees starting in September 2006. None of the courses in the trial is in science or mathematics. The two-year first degrees will schedule extra teaching over the summer months leading to intensive courses similar to those pioneered at the University of Buckingham, the UK's only private university. It is clear that, while widening the range of options open to students, such an approach would have significant consequences for the teaching commitments of academic staff.

Other undergraduate qualifications

Other undergraduate qualifications cover a range of other courses, largely offered part-time, including HNCs/HNDs

and Foundation Degrees. Introduced in 2001, Foundation Degrees are a new vocational qualification intended to develop specialist knowledge and employability skills taking the equivalent of two years of full-time study. Foundation Degrees are designed in collaboration with employers and provide an alternative route to HNCs/ HNDs for students wishing to undertake 'sub-degree' HE qualifications. While a Foundation Degree is a recognised qualification in its own right, it also enables students to seek entry to the final year of a specified honours degree course.

Foundation Degrees should not be confused with 'foundation year' or access courses, which are designed to provide a route into foundation degrees or first degrees for those who have not achieved the necessary A-level qualifications.

3.2 The expansion of participation in HE

3.2.1 Long-term trends

In common with virtually every other country in the world, participation in UK HE has dramatically increased over the past century. Much of this expansion has taken place over the past 40 years and changes in the undergraduate education system need to be seen in the context of this major increase in participation.

Figure 3.2 shows how participation in UK HE has increased since the early 1960s. The Age Participation Index (API) is

Figure 3.2. Participation by young people in HE, 1961/62 to 2004/05 (DfES).
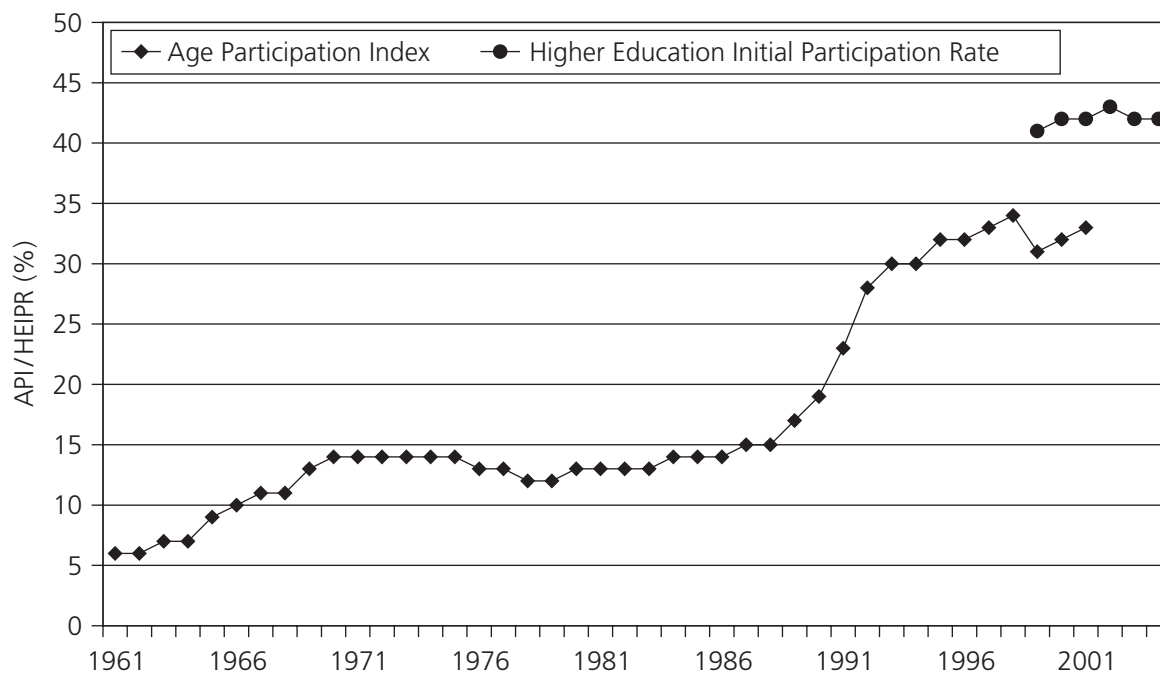
the number of UK-domiciled under-21-year-olds entering full-time or sandwich courses at HE institutions as a percentage of the average 18- to 19-year-old population. The slight dip in the API in 1998/99 coincides with the introduction of tuition fees for undergraduate courses. From 2001/02, the API was replaced by the Higher Education Initial Participation Rate (HEIPR). The HEIPR includes part-time students and those participating in HE for the first time aged 21–30 who were not included in the API. It is noticeable that the HEIPR has remained fairly constant over the past few years.

The expansion shown in Figure 3.2 in the mid-1960s and early 1990s is less dramatic than it appears, in that students taking sub first-degree qualifications (eg HND/C and advanced professional qualifications: accountancy, banking and nursing) were not included in the figures up to the 1990s, although these courses were HE. Many of these qualifications were taken part-time, often with day-release from work. Most students who might previously have followed this part-time route now take full-time first degrees, although these may be less oriented towards science and technology subjects, and may still require part-time further study for professional qualifications.

The increase in the number of graduations per year since the 1960s has, of course, increased the number of graduates in the working population, as these graduates replace non-graduates retiring from this population. This is considered further in section 7.1.2.

3.2.2 The past decade

Since the late 1980s, successive UK governments have pursued policies to widen access to HE and increase overall participation. The present Government's aim of increasing participation in HE towards 50% of those aged 18–30 by 2010 is measured through the HEIPR. The White Paper on the future of HE (DfES 2003) anticipated that the bulk of this expansion would come through Foundation Degrees. This section explores in broad terms where the increases have been.

Figure 3.3 shows how the number of UK-domiciled students in the first-year of studying for a first degree has changed over the past decade. There was a 25% increase in the number of UK-domiciled first-year undergraduates studying for first degrees between 1995/96 and 2004/05, with a 17% increase in full-time students and an 89% increase in part-time students.

However, the main expansion in undergraduate education over this period has been in those qualifications classified as 'other undergraduate', a category that includes Foundation Degrees and HNC/HNDs. The number of UK-domiciled students in the first year of studying for an 'other undergraduate' qualification is shown in Figure 3.4. There was a 105% increase in these students between 1995/96 and 2004/05, almost entirely associated with part-time students, who now account for 69% of the UK-domiciled first-year other undergraduate students.

Key points to note are the:

- large increase in the number of students studying for non-first-degree undergraduate qualifications, and the smaller, but significant, increase in those studying for first degrees;

Figure 3.3 UK-domiciled first year students studying for first degrees, 1995/96 to 2004/05 (HESA 1997–2006a).
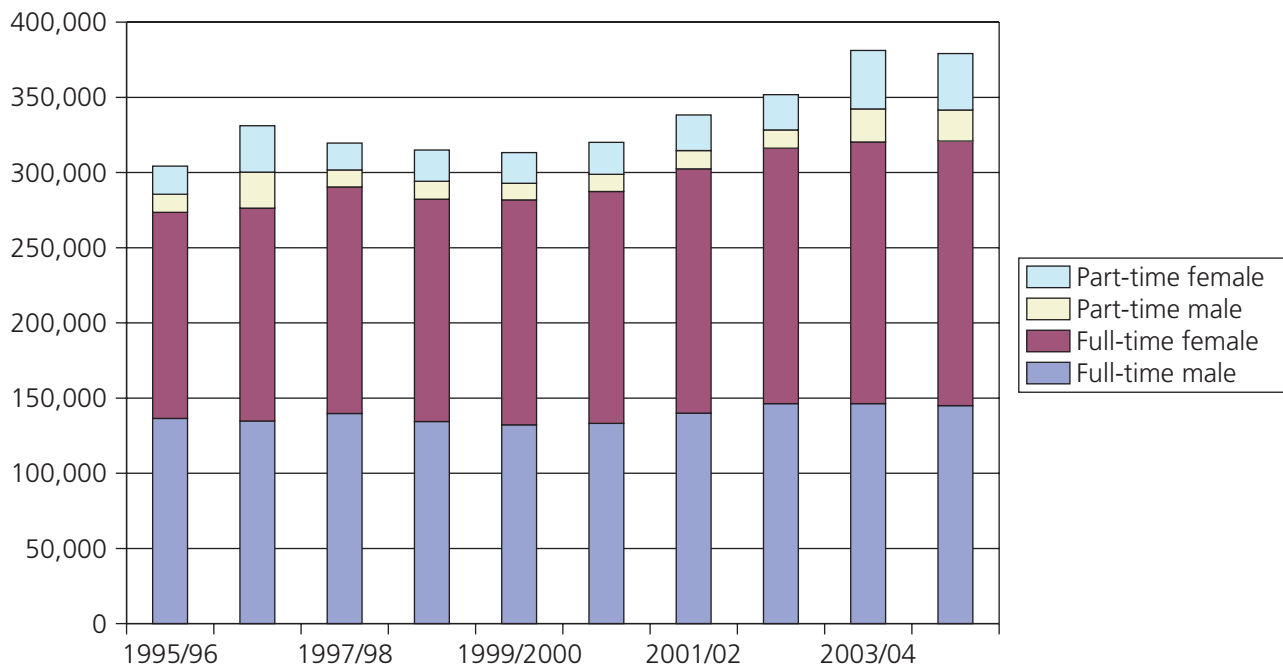
Figure 3.4. UK-domiciled first year students studying for other undergraduate qualifications, 1995/96 to 2004/05 (HESA 1997–2006a).
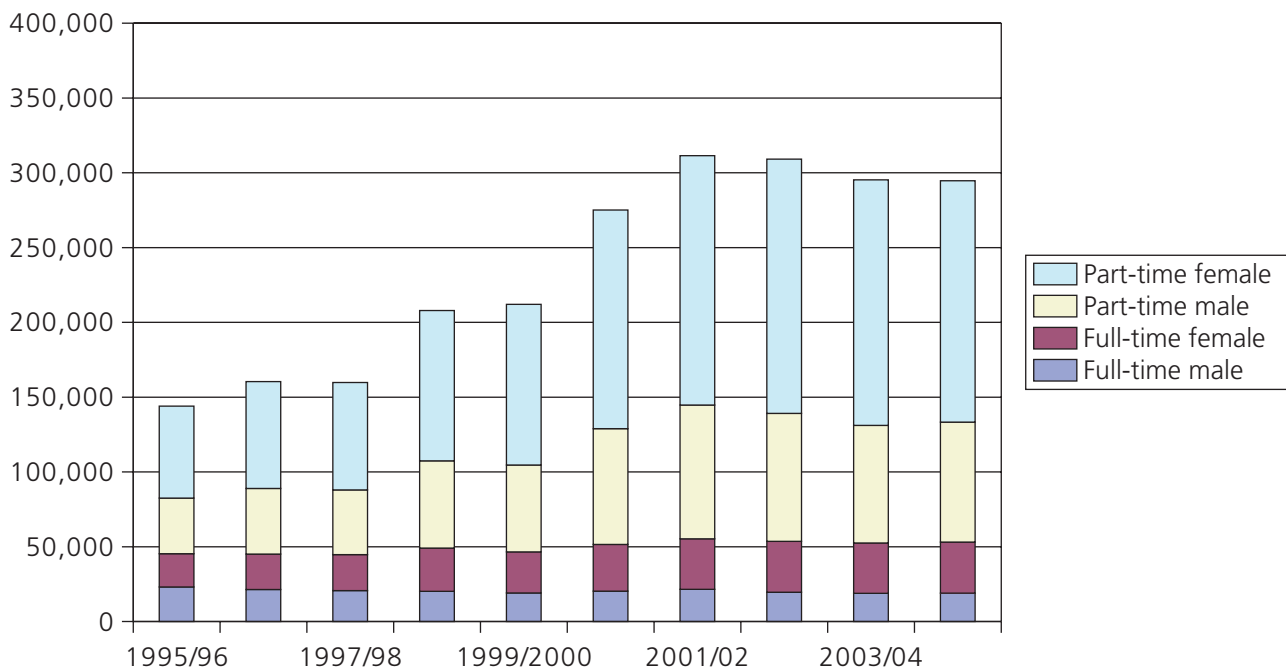
Note: Data returned by the Open University in 1996/97 provided for the first time a split between part-time first year students and part-time students in other years. Prior to this, the number of first year part-time students was undercounted. However, from 1997/98, all OU students are recorded as studying for other undergraduate qualifications rather than first degrees and therefore appear in Figure 3.4 rather than Figure 3.3.

Table 3.1. Academic staff in all UK HE institutions 1998/99 and 2003/04 (HESA 1997–2006b).

	1998/99			2003/04		
	Full-time	**Part-time**	**Total**	**Full-time**	**Part-time**	**Total**
Teaching only	6,396	5,570	11,966	6,295	23,860	30,155
Teaching & research	71,415	8,784	80,199	69,570	12,105	81,675
Research only	34,563	4,422	38,985	29,870	6,330	36,200

- noticeably larger increase in the number of women studying at undergraduate level compared with the number of men;

- growing importance of part-time study, particularly among women and those studying at the non-first-degree undergraduate level.

In 2004/05 there were just over 52,300 non-UK-domiciled first-year first degree students (12% of the total first-year first degree students), largely studying full-time, up from 36,800 in 1995/96. In 2004/05 there were 23,600 non-UK-domiciled first-year other undergraduates; of these nearly 40% were studying full-time.

3.3 HE teaching

3.3.1 Staffing of universities

HESA publishes data on professional staff undertaking the academic functions of teaching and research, and hence these include post-doctoral researchers. Information on faculty numbers are more difficult to obtain. One approach is to use the figures for those employed for teaching and or research. These, however, are significantly greater than those quoted by DfES for permanent members of academic staff (DfES 2006b).

Table 3.1 shows the number of academic staff as defined above in all UK HE institutions in 1998/99 and 2003/04 split by whether they are involved in teaching-only, in teaching and research, or in research-only. The proportion of staff engaged in research only has remained roughly constant over this period.

Within the total figures there have been significant differences at the subject level. A recent DfES report (DfES 2006b) indicated that over the period 1995/96 to 2003/04 the number of permanent academic staff in chemistry, physics and mathematics declined by 10% and in engineering, technology, building and architecture by 14%, compared with a 16% overall increase, and a 42% increase in creative arts and design.

3.3.2 Staff development

The UK HE sector has over 100 courses in teaching, learning and academic practice designed to improve the teaching skills of academic staff. The first such programmes in the UK were developed in the late 1980s and their numbers have continued to grow in response to calls to enhance the professional status and quality of teaching (as exemplified in the White Paper on the future of Higher Education (DfES 2003)).

The programmes are accredited by the Higher Education Academy (HEA). A recent evaluation (HEA 2006) has found evidence that the programmes can be successful in helping participants become more student-focused and less teacher-focused in the way that they see their teaching. However, the time and effort required to complete the programmes were questioned by nearly a quarter of 400 recent participants. In particular, the evaluation recognised that there are many varied pressures on new and inexperienced academic staff trying to establish their careers, and the value of completing a teaching programme at the start of an academic career was questioned.

3.3.3 The relationship between teaching and other university activities

A key feature of HE teaching is the high level of scholarship[1] required, and the necessary staff time for this activity is insufficiently taken account of in central funding, exacerbating the shortfall on the funding of teaching. The issue is complicated by the relationship of scholarship with other activities that enhance it, such as active research and professional development – including close interaction with innovative employers of relevant graduates, attendance at international meetings, and collaboration with professional colleagues in the public services and business sectors.

The importance of research activity within departments has featured in the discussions on recent closures of STM courses (see section 5.3). However, research activity can take many forms, including the collection and analysis of

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[1] There are many definitions of scholarship. For the purpose of this report it is defined as a deep understanding and ongoing engagement with the concepts, ideas, methodology and analysis being taught.

new data, modelling, and the analysis and synthesis of existing data. Although the cost of such activities can vary greatly, at a minimum it is necessary to cover the relevant cost of faculty time.

The relationship between teaching and research was the subject of a review by the HE Research Forum, which was set up jointly in 2003 by the then Minister for Lifelong Learning and Minister for Science and Innovation (DfES 2004b). This reported that those students who are not learning in an HE environment that is informed by research, and in which it is not possible to access research-related resources, are at a disadvantage compared with those that are. Accordingly it recommended that those universities that have a low level of HEFCE research funding should receive funding to support research-informed teaching. This recommendation was accepted by the Government and subsumed within the HEFCE funding calculations for the Teaching Quality Enhancement Fund. This would largely benefit those STM courses in some post-1992 universities.

3.4 The funding of HE teaching

3.4.1 Sources of university income

Within the UK HE system, universities position themselves in different ways. Some are research-led, others focus on teaching, whereas many seek to excel in both. Institutions have differing degrees of engagement with their communities, and with local, national and multinational businesses. Thus in this analysis it is helpful to subdivide the sector, accepting that in some cases the boundaries will be blurred. This subdivision does not imply any hierarchy or other value judgement of institutions: it merely acknowledges that differences exist within the university sector. The three groups used (Annex 2 details institutional membership) are:

- Russell Group

- Other pre-1992 universities

- Post-1992 universities

Universities receive their funding from a variety of sources, and the proportion of a university's income intended for its teaching activities varies considerably across the sector, as shown in Figure 3.5. In the four universities with the highest overall income in 2003/04 (Cambridge, Oxford, Imperial College and University College London), funding dependent on teaching represents only 22% of total income. However, in the post-1992 institutions, teaching income represents, on average, 67% of total income. This variation has several important consequences, including the need to cover adequately the full costs of teaching. These costs not only include the direct cost of teaching students, but also the costs of the necessary scholarship to enable staff to keep up with developments in the subject,

Figure 3.5. Sources of university income by institutional grouping, 2003/04 (HESA 1997–2006b).
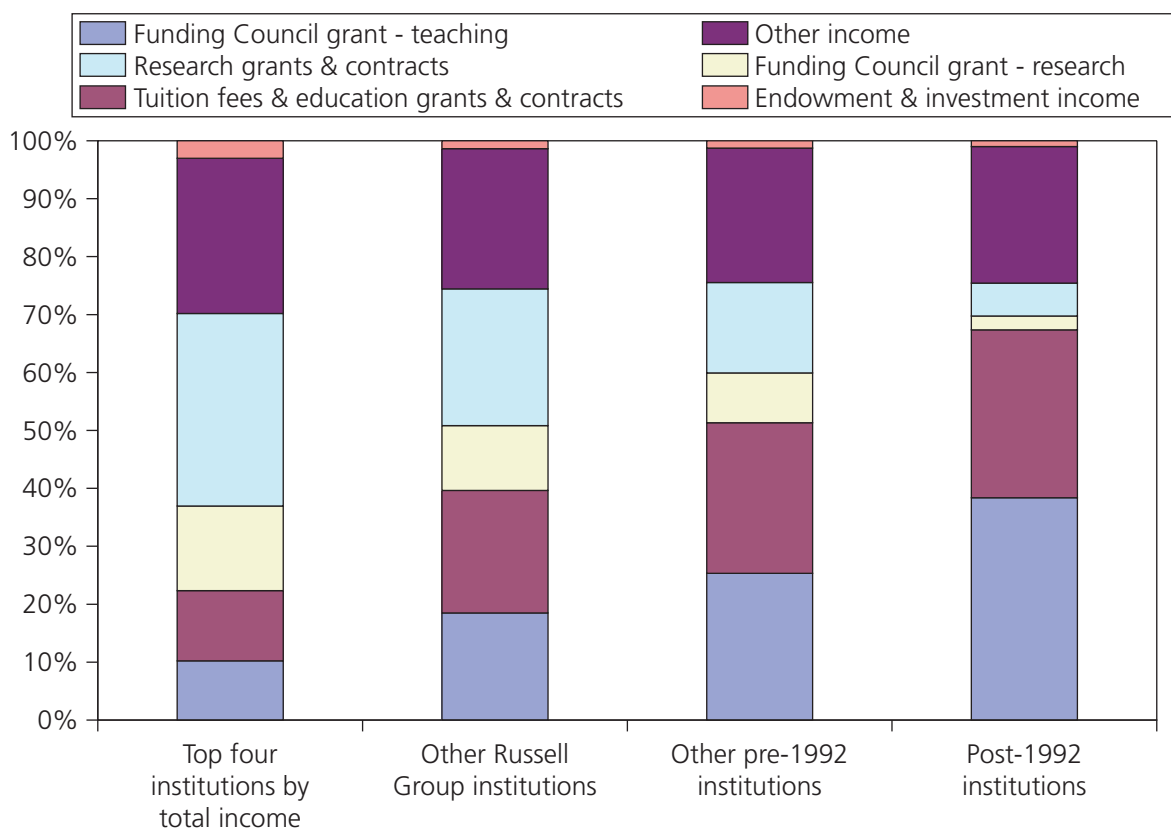
Figure 3.6. Sources of HE institution teaching income (whole sector), 1998/99 to 2004/05 (HESA 1997–2006b).
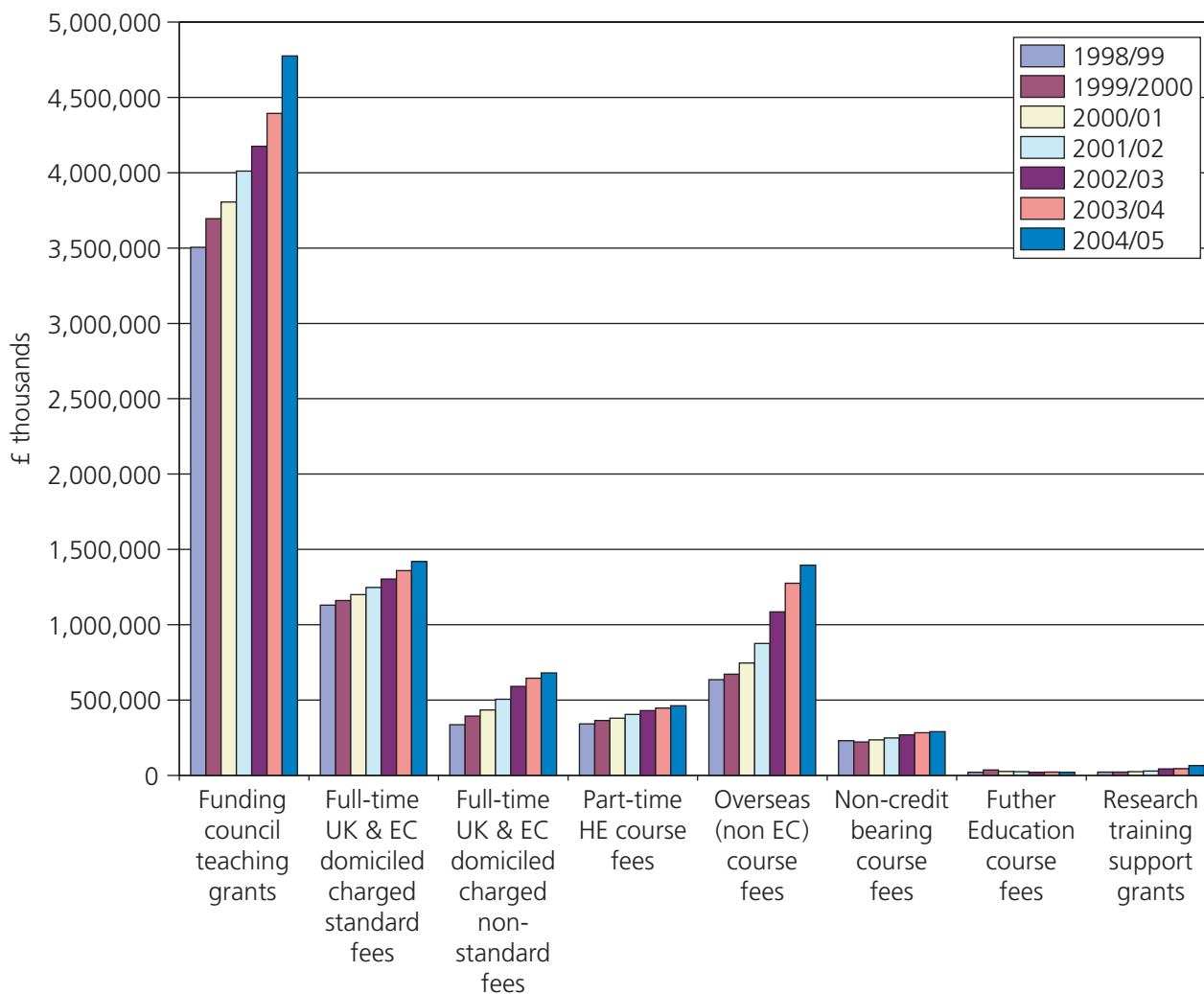
and liaison activities with, for example, potential employers of graduates appropriate for the particular subject.

Looking at income for teaching the overall situation between 1998/99 and 2004/05 is shown in Figure 3.6.

Despite the significant increases in funding council teaching grants, this now represents a decreasing share of the total funding, with course fees from non-EU overseas students becoming, proportionately, an increasingly important source of funding. The number of international students choosing to study in the UK is highly dependent on several factors including exchange rates, UK Government policy and the policy of the government in the student's home country; for these reasons income from overseas course fees is likely to be volatile.

3.4.2 Public and fee income per UK-domiciled student

It is difficult to get reliable figures for the income per student, particularly a figure that is meaningful in terms of the differences between full and part-time students and undergraduate and postgraduate students, or between different disciplines. Nevertheless it is clear that there was a major reduction in the unit funding of students over the past 20 years up to about 2000. Although the unit income has stabilised through the introduction of student paid fees, it has not risen significantly since then, although the introduction of variable and higher fees in 2006 should have a positive effect on the unit income.

3.4.3 The cost of teaching

Universities will be aware of the overall costs of their various activities, including teaching, and some will have disaggregated information to departmental level and to various levels of courses. However, sector-wide figures will not be available until the new Transparent Approach to Costing (TRAC) exercise is completed across the sector for teaching. The pilot implementation will be in 2006/07, with robust figures expected to be reported by February 2008.

The requirement for full costing for the teaching function is particularly important in the UK because, almost uniquely, the UK public funding for HE has separate streams for teaching and underpinning research. Laboratory-based projects in the final year of BSc honours courses are especially expensive, and laboratory-based subjects have been particularly badly hit when research income from the Funding Councils has been cut. Furthermore, the funding of STEM courses in England has been reduced after the reduction from 2.0 to 1.7 in the weightings used in the formula for calculating the block teaching grant for laboratory based subjects (HEFCE 2004). The Society expressed the view in its response to the House of Commons Science and Technology Committee inquiry into strategic subjects (Royal Society 2005) that teaching, particularly in STEM subjects, was under-funded and subsidised from research activities, and possibly from lower-cost teaching activities. It is essential to have firm TRAC data to inform a sustainable future funding of laboratory-based courses.

4 The STM post-16/HE interface: students, skills and knowledge

In this chapter the post-16/HE interface is explored in terms of trends in post-16 science and maths uptake and the skills and knowledge that it is important for students to develop at this stage of their education, particularly in preparation for a first degree in an STM subject.

Section 4.1 investigates trends in post-16 science and mathematics uptake in terms of student choice, trends in A-level entries and combinations and the Government's recently announced targets to increase the number of students taking A-levels in physics, chemistry and mathematics as part of its ambitions to improve the quality of STEM education and increase the supply of STEM skills (HMT 2006a). Section 4.2 considers the potential pool of STEM undergraduates, comparing the number of students achieving A-levels and Scottish Highers with the number of first year undergraduates in relevant subjects, as well as discussing other routes to HE study. Finally, section 4.3 discusses how A-level and equivalent qualifications prepare students for STM first degrees, highlighting concerns about the mathematical skills of new undergraduates and considering how the gap between pre-19 education and HE can be bridged.

4.1 Trends in post-16 science and mathematics uptake

4.1.1 Student choice post-16

A wealth of research exists concerning the many influences on young people's (pre- and) post-16 educational choices (see, for example, ETB 2003 and references; Donnelly & Jenkins 2006). These influences include: curriculum structure; curriculum content; the range of subject options, including 'newer' subjects such as psychology, ICT and media/communications studies; access to dynamic specialist subject teaching; the quality of careers advice available; students' and their families' socio-economic status; parents' educational and career background; perceptions of science and scientists such as those promulgated by the media; and relative subject difficulty. Unfortunately, little is known about how these factors, and others, interact to shape young people's subject choices.

Of these influences, perceived subject difficulty has aroused particular concern arising from the extensive evidence base that has been established by the Curriculum, Evaluation and Management Centre at the University of Durham. This research suggests that although the proportions of students achieving A-grades in the physical sciences exceeds those gaining A-grades in many arts subjects, fewer physical science students achieve a grade A at A-level than would be expected from their average GCSE scores. Many factors could be

responsible for this, including various of those listed previously to greater or lesser degrees. The causes and effects of these trends merit research in themselves. This issue serves ably to demonstrate just how complex the various elements affecting student choice are.

4.1.2 Trends in A-level entries

A-levels are currently the most common route into science and mathematics subjects at HE level. Over the past decade there has been an increase in the overall number of students taking A-levels, both because of increasing cohort sizes and an increase in the proportion of students staying in education post-16. In 2006 there were 806,000 A-level entries in the UK compared with 731,000 entries in 1992, an increase of 10%.

Within this context of increasing overall numbers there have been decreases in the number of entries to some science subjects and to mathematics. Figure 4.1 shows A-level entries in the main science subjects and mathematics (including further mathematics) in England, Wales and Northern Ireland from 1991 to 2006 and entries to further mathematics (16- to 19-year-olds in England only) from 1996 to 2005.

There have been decreases of 6% in the number of entries to chemistry (from 43,000 to 40,000), 34% in physics (from 41,000 to 27,000) and 13% in mathematics and further mathematics (from 72,000 to 63,000), with the decrease occurring mainly in mathematics rather than further mathematics, although chemistry has recovered slightly from a low of 36,000 in 2003. Entries to biology A-level have fluctuated but increased 13% overall during this period (49,000 to 55,000).

The sharp decrease in mathematics entries between 2001 and 2002 is linked with the introduction of the two-part A-level, with an option to drop the subject after the first (AS) year, coupled with problems with the relative difficulty of the mathematics AS level in 2000/01 (Smith 2004). There has been a modest recovery since then. Unfortunately the JCQ data on entries only started reporting further mathematics A-levels separately from mathematics A-levels in 2004. In Figure 4.1, the mathematics and further mathematics data have been added for 2004–2006 to maintain a continuous series and therefore include about 6,000 further mathematics entries. The DfES data show that further mathematics entries by 16- to 19-year-olds in England have been remarkably stable over the past ten years. This would appear to indicate that A-level mathematics courses have been able to continue to attract the most able mathematicians.

The recent fall-off in entries in science and mathematics A-levels relative to total A-level entries is shown in

Figure 4.1. A-level entries (England, Wales and Northern Ireland) in science and mathematics (including further mathematics), 1991–2006 (JCQ data) and 16–19 year old entries (England only) in to further mathematics, 1996–2005 (DfES data).
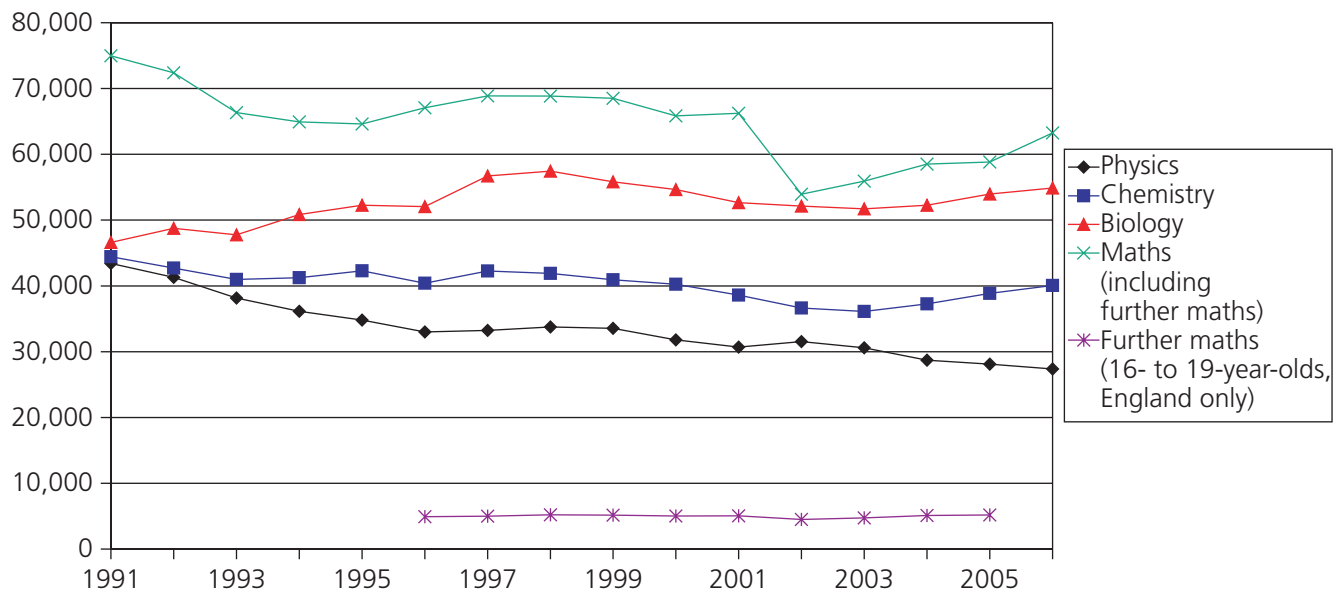
Table 4.1. A-levels in mathematics, further mathematics and comparator subjects as a percentage of all A-level entries, 2001–2004 (QCA (2006); chemistry and biology added from JCQ data).

	2001	2002	2003	2004
All A-levels	100.0	100.0	100.0	100.0
Biology	6.8	7.4	6.9	6.8
Chemistry	5.0	5.2	4.8	4.9
Mathematics	9.0	6.8	6.6	6.7
Further mathematics	0.9	0.7	0.7	0.7
Physics	4.7	4.4	4.0	3.7
English	12.5	11.5	10.9	10.8
Geography	5.8	5.1	4.9	4.6

Table 4.1. English and geography, included as comparator subjects, have also been losing market share, but it is clear that mathematics has recorded the most severe fall of the subjects considered. The recent Qualifications and Curriculum Authority (QCA) interim report on the evaluation of participation in A-level mathematics (QCA 2006) notes that the subjects that have gained market share over this period are 'newer' subjects such as psychology, ICT (information and communication technology) and media.

It should be noted that apart from the maintenance of numbers entering for further mathematics there is other evidence that the fall in overall numbers entering A-level mathematics, physics and chemistry has been largely in less able students in these disciplines. The numbers of those achieving A grade passes has actually increased

(eg for mathematics QCA 2006), and while some of this may be due to better teaching, etc, it is likely that those who believe that they will achieve a better grade in another subject have dropped one or more of these disciplines. The increase in the proportion of entries gaining an A-grade was particularly marked in mathematics between 2001 and 2002, mirroring the significant drop in entries shown in Figure 4.1.

In 2005, three STM subjects appeared in the top ten A-level subjects: biology (ranked third), mathematics (ranked fourth) and chemistry (ranked eighth) with 6.9, 6.7 and 4.2% of the total A-level entries respectively (JCQ 2006). The most popular subject was English (11.0% of A-level entries); psychology was ranked fifth with 6.4% of overall entries.

Annex 3 details trends in Scottish Highers entries.

4.1.3 The Government's ambitions for increasing uptake

The Government's *Science and innovation investment framework 2004 – 2014: next steps* (HMT 2006a) outlines the Government's new ambitions for improving the quality of STEM education and increasing the supply of STEM skills. The document includes a commitment to, 'work with schools and other partners, with the aim of achieving year on year increases in the number of young people taking A-levels in physics, chemistry and mathematics so that by 2014 entries to A-level physics are 35,000 (currently 24,200); chemistry A-level entries are 37,000 (currently 33,300); and mathematics A-level

entries are 56,000 (currently 46,200)'. Welcome as this commitment is, no basis for these targets is offered in *Next steps*, and it is unclear whether these figures take account of projected demographic trends. Although the number of 18-year-olds is set to increase slightly up to 2009, there is a downturn from 2010.

4.1.4 Combinations of A-level subjects

The large number of different subject combinations available to post-16 students, and the opportunity of taking AS-levels in several subjects and then A-levels in a subset of these, has led to an increasing diversity in the combinations of subjects that students study. Although the increased breadth of knowledge that stems from studying more subjects post-16 is valuable, for many first degree STM courses particular combinations of A-level subjects remain important. It is vital that 16- to 19-year-olds aiming for particular courses in HE are able to access appropriate advice about their choices.

Figure 4.2 shows data from the recent QCA report (QCA 2006) on participation in A-level mathematics, illustrating the most popular combinations of three or more A-levels that include mathematics.

The report notes that the actual numbers of students taking these combinations including mathematics have shown substantial decreases, despite the greater number of students taking A-levels overall. However, as shown in

Figure 4.1, mathematics entries underwent a substantial fall between 2001 and 2002 and this will have impacted on the number of students taking combinations of subjects which include mathematics. The only combination that has remained stable over this period is the four A-level combination of biology, chemistry, physics and mathematics. The report suggests that this is because it is not prone to the 'dropping down' effect, where students drop a subject after AS-level, because it will have constituted a students' entire programme from the start of their AS studies.

The report also indicates that students are taking more varied combinations of subjects: the total number of subject combinations in 2001 was 86,960 (studying at least three A-levels, excluding general studies), and by 2002 the number of subject combinations had risen to over 100,500 with 6.45% of these combinations being taken by one candidate only.

4.2 The potential pool of STM undergraduates

4.2.1 A-levels and Scottish Highers

To assess the number of suitably qualified students who could, should they choose to, enter STM HE, this chapter compares the numbers of science and mathematics A-levels and Scottish Highers and Advanced Highers (referred to here collectively as Highers) achieved in summer 2003

Figure 4.2. Most common combinations of at least three A-levels including mathematics in 2001, 2002 and 2003 (QCA 2005).
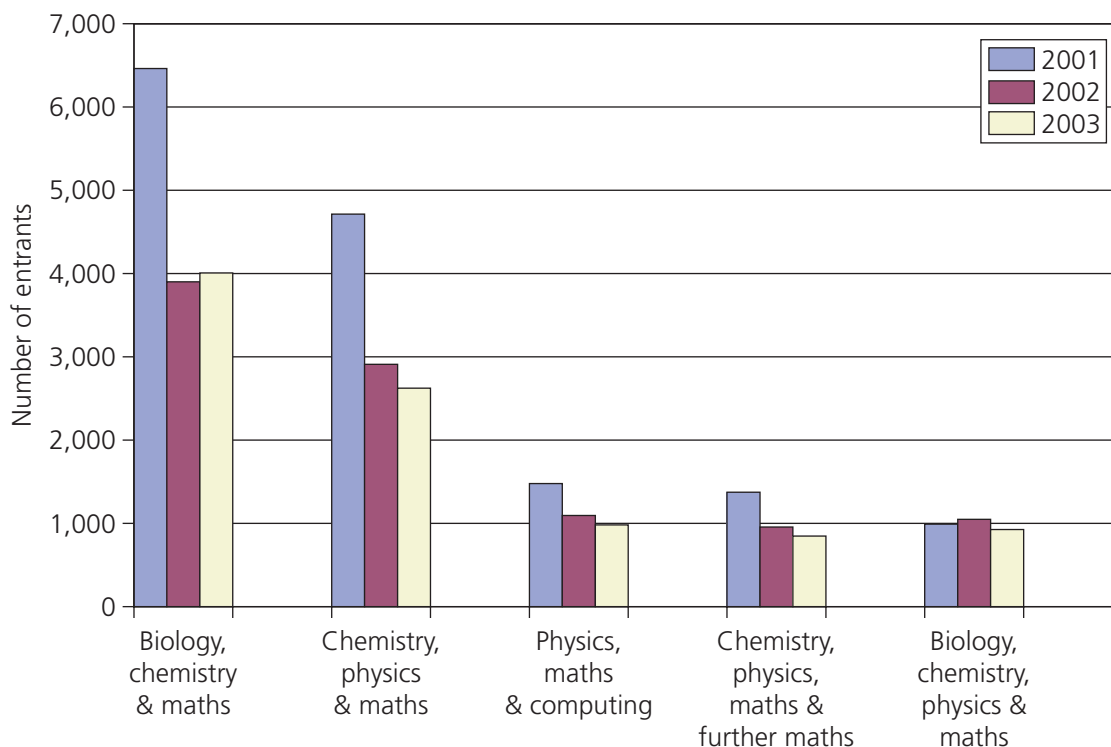
with the number of UK-domiciled students in the first year of a relevant STEM first degree that autumn. There are, of course, other entry routes to first degrees for UK residents, and these provide important alternative pathways to HE study, not least for the individual concerned. However, the number of students achieving vocational A-levels or International Baccalaureate qualifications is small when compared with the number studying A-levels and Highers. These alternative routes are therefore considered separately in section 4.2.2.

There are several complicating factors that it is important to take into account in a simple exploration of the relationship between A-level (and Scottish Highers) qualifiers and the numbers starting first degree courses. For example, A-level qualifiers may not enter HE in the same year that they achieve their award. The most important of the options open to those with A-level/Scottish Higher passes are:

(a) taking a year (or years) out after A-levels and entering a first degree course in a later year;

(b) taking a full A-level in the first year of the sixth form (year 12) – for example, students taking mathematics in a single year and further mathematics in the subsequent year;

(c) entering into a non-STM, medicine or engineering degree, having studied one or more science/mathematics A-levels;

(d) entering into employment or entering into HE in another country.

Except when there are specific issues that may lead to a distortion of the system, such as the introduction of new funding arrangements (such as tuition fees) or major changes in the number of students achieving an A-levels in a particular subject, for (a) and (b) the year-to-year effects are likely approximately to offset each other and hence for simplicity A-levels in a particular year are considered against degree entrants in that year. Factors (c) and (d) mean that the A-levels obtained in a particular subject represent the maximum pool of potential students; this is unlikely to be offset by those entering HE with qualifications other than A-level.

As certain A-levels are seen a prerequisites for first degree courses, the entries and then the results determine the overall pool of potential students available for entry to a particular discipline. A comparison of A-level outcomes and entries to first degree courses is considered below. In all cases, of course, and particularly with mathematics, a significant number of young people with STM A-levels

Figure 4.3. A-levels and Scottish Highers achieved in mathematics in 2003 (left) and UK-domiciled first-year first degree students in related subjects in 2003/04 (right) (JCQ, SQA and HESA data).

A-levels and Scottish Highers awarded   First-year first degree students
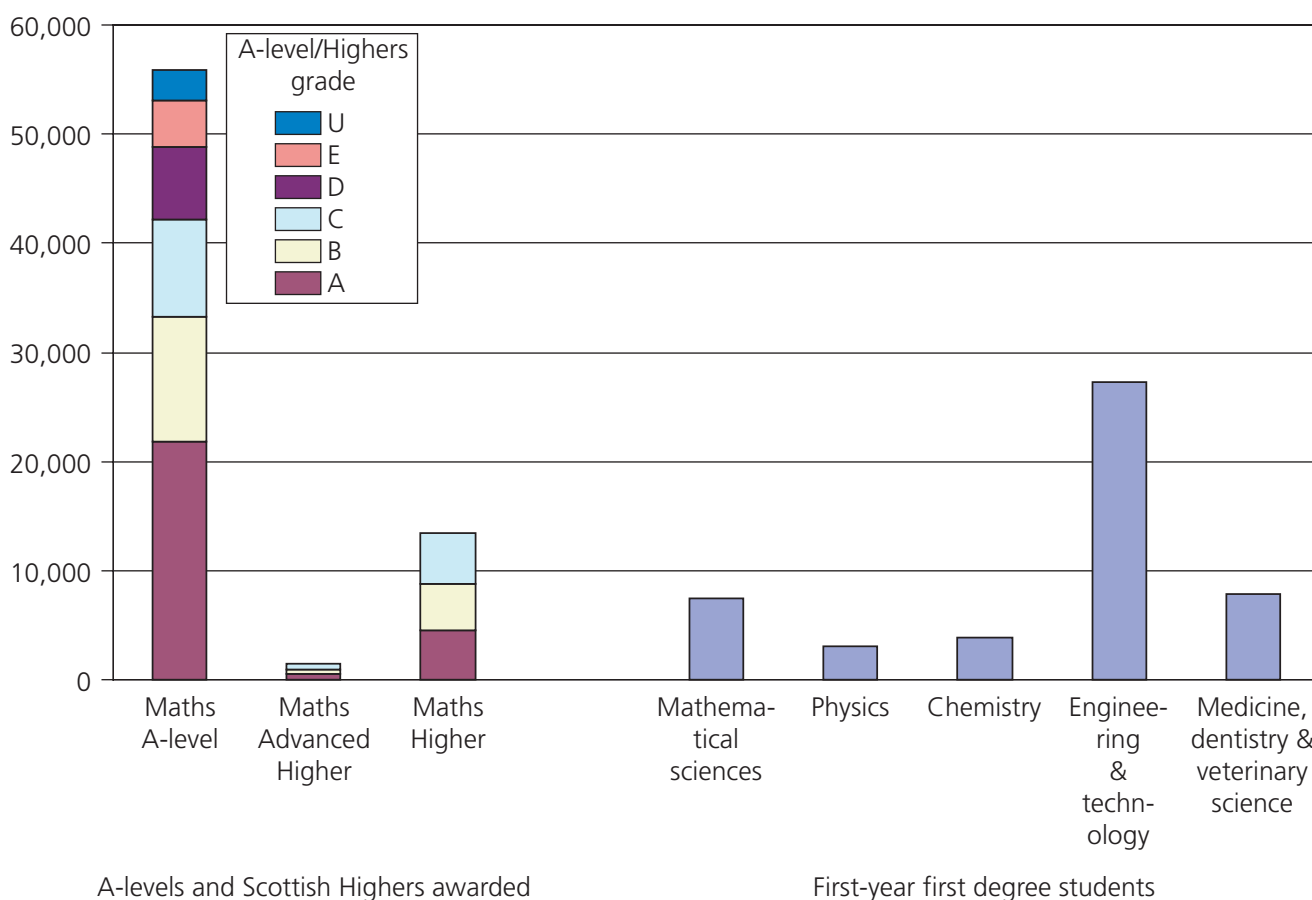
and Highers will choose to read non-STEM first degrees. This is healthy, but means that the actual pool of those with relevant A-levels for STEM subjects is lower than the raw A-level (and other) passes would indicate.

Mathematics

The number of students taking A-levels and Highers in mathematics in the summer of 2003 is shown in Figure 4.3, together with the number of UK-domiciled first-year first degree students in 2003/04 for the main STEM subjects where A-level mathematics is generally seen as a prerequisite. These A-level numbers overstate the actual number of people with A-level mathematics or equivalent, because a proportion (some 6,000) of the most able mathematics students will have taken two A-levels in mathematics. Furthermore, as indicated above, many young people with A-level mathematics choose to read non-STEM subjects.

From Figure 4.3, even if all of the students who study for first degrees in the mathematical sciences have achieved an A grade at A-level/Advanced Higher, there would still have been a significant number available to study other subjects at HE level, including those where a high levels of

mathematical ability are important, for example, physics, engineering & technology, and chemistry.

On the other hand, it is also clear that with the wide range of first degree courses taken by those with mathematics A-levels or Highers, including for example economics for which good A-level or Higher mathematics is often required, the numbers achieving A–C grades could well be a limiting factors in the number of students taking physical sciences, engineering and technology courses.

Chemistry

An equivalent set of data for chemistry is shown in Figure 4.4. Most entrants to medical, dental and veterinary courses are required to have chemistry A-level or equivalent. Other subjects that rely on an adequate supply of A-level/Advanced Higher chemistry students are also shown in the figure.

Since entry to medicine, dentistry and veterinary sciences courses is highly competitive, often requiring three A-grades at A-level, it seems that these subjects must take a high proportion of the students achieving the top grade in A-level/Advanced Higher chemistry.

Figure 4.4. A-levels and Scottish Highers achieved in chemistry in 2003 (left) and UK-domiciled first-year first degree students in related subjects in 2003/04 (right) (JCQ, SQA and HESA data).
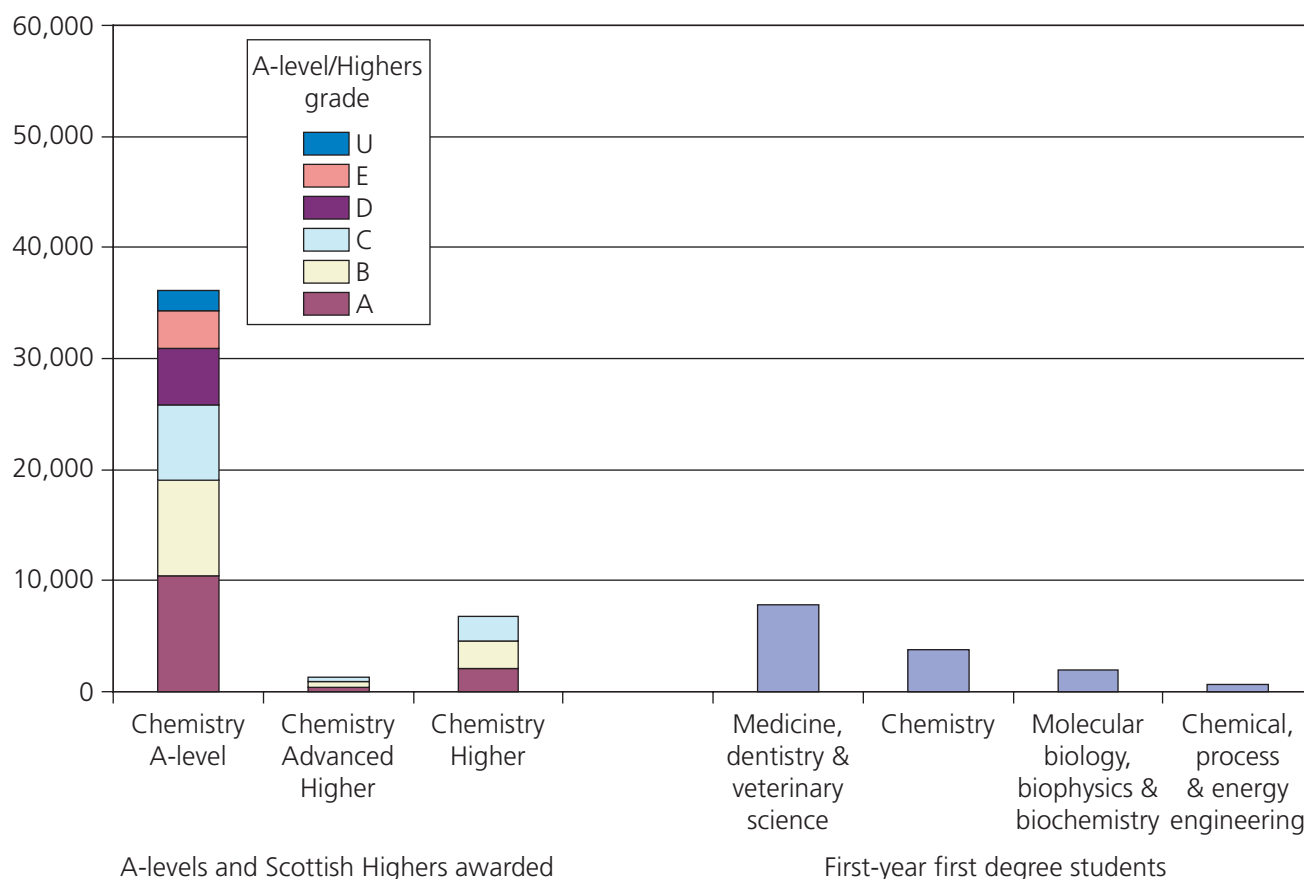
The expansion of medical school places during a period in which entrants to chemistry A-levels have decreased (as shown in Figure 4.1) compounds this effect. The recommendations of the Medical Workforce Standing Advisory Committee (MWSAC) in December 1997 (DOH 1997) and the commitments outlined in the NHS Plan in July 2000 resulted in almost 2,150 new medical school places being allocated to HE institutions in England between 1999 and 2001, the largest increase since the NHS was established. Between 2001 and 2004, four new medical schools and four new centres of medical education were opened. In 2004/05 there were 6,300 entrants to medical school compared with 3,700 in 1997, an increase of 70%. Since there has been no concurrent increase in the number of students studying chemistry post-16, the pool of students who could study chemistry at first degree level has declined.

It is of note that every year since 1996 there have been more acceptances to chemistry degrees than there were applicants (this is possible because when students apply to more than one subject area, they are recorded by UCAS as applicants to the subject listed most frequently on their application form), which indicates that several of these acceptances are for students falling back on their second or third subject choice, or entering HE through clearing. It is possible that some of these are students who failed to make the very high grades required for medicine, but who

nevertheless may still have high UCAS points. This is considered further in section 5.2.4.

Biology

A similar situation is apparent in biology, as shown in Figure 4.5. Here the main first degree target subjects identified are medicine, dentistry and veterinary science and the biological sciences. Biology and molecular biology, biophysics and biochemistry have been separated out from the HESA 'biological sciences' category. 'Other biological sciences' includes the rest of the subjects classified as 'biological sciences' by HESA, including subjects as diverse as botany, psychology and sports science.

Since 2002, biology courses have had more acceptances than applicants.

Again, it is clear that many students achieving the highest grades at biology A-level/Advanced Higher will enter medicine, dentistry or veterinary science, leaving fewer A-grade students for other subjects.

Physics

Finally, Figure 4.6 shows the situation in physics, where physics and engineering & technology are identified as the main degree subjects requiring physics at A-level or

Figure 4.5. A-levels and Scottish Highers achieved in biology in 2003 (left) and UK-domiciled first-year first degree students in related subjects in 2003/04 (right) (JCQ, SQA and HESA data).

A-levels and Scottish Highers awarded

First-year first degree students
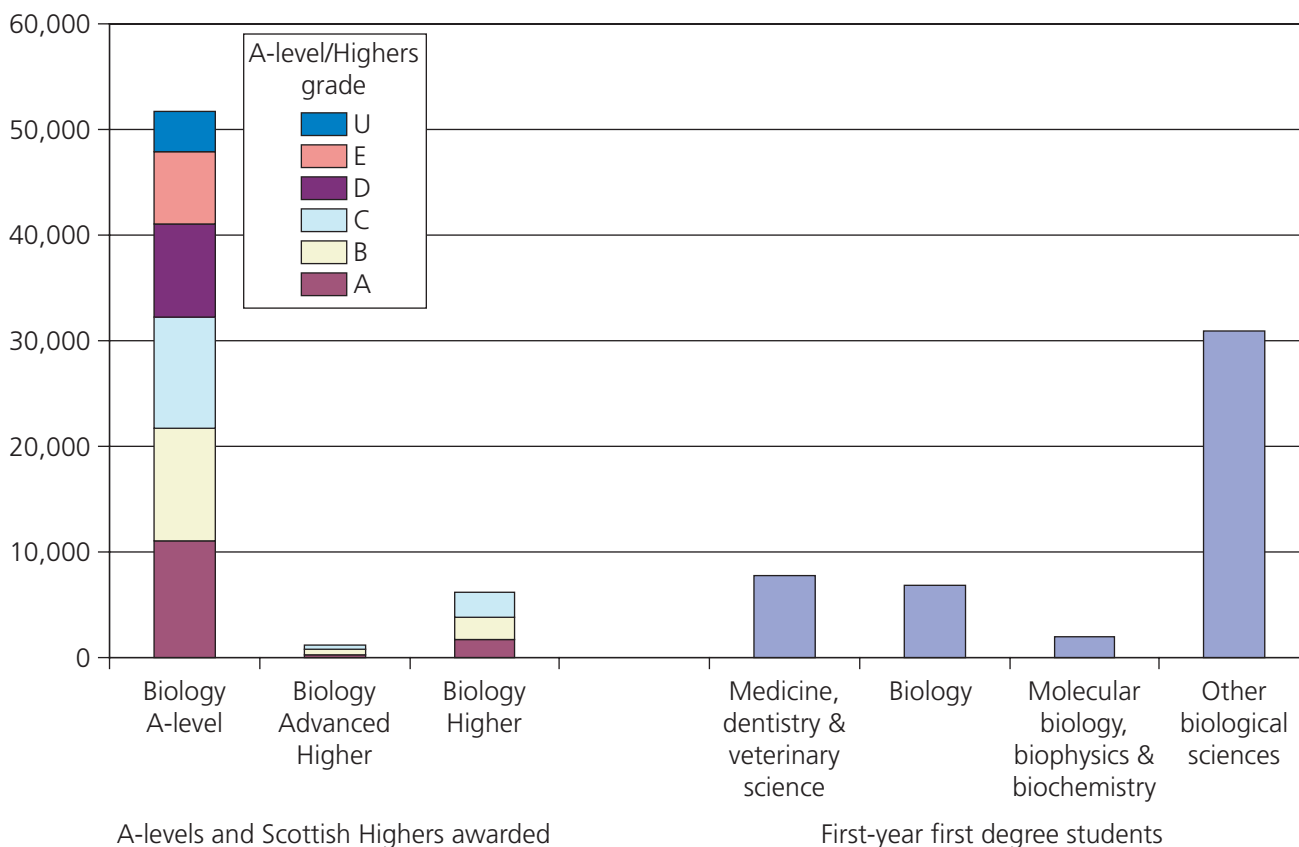
equivalent with physics A-level also being an appropriate preparation for many mathematical sciences, chemistry and computer science courses. Figure 4.6 shows that A-levels and Highers would appear to be a constraining factor on recruitment to physical science, engineering and technology courses.

4.2.2 Other routes into HE

Vocational A-levels

Vocational A-levels, introduced to replace the Advanced-GNVQ qualification in September 2000, emphasise knowledge, skills and understanding in broad vocational areas. From September 2005, Vocational A-levels (previously VCEs) were renamed as GCEs with the word 'applied' in their title where necessary to distinguish them from traditional GCE qualifications.

Although potentially an important entry route to some areas of HE, and for some individuals for STM subjects, the numbers taking vocational A-levels that would be a valid precursor for STM courses is small. In 2005, 956 students sat a single-award science VCE (equivalent to a single A-level) and 952 students sat a double-award science VCE (equivalent to two A-levels); 447 students sat the single VCE in engineering and 487 the double VCE in engineering (JCQ data).

International Baccalaureate

The number of schools offering the International Baccalaureate (IB) in the UK has risen from 22 in 1997 to 87 in 2006, whereas the number of IB diploma candidates has increased from 1,040 to 2,400 over the same period (International Baccalaureate Organization, personal communication). The large rise in schools offering the IB could see it becoming a more important route into HE for UK-domiciled students. However, at present the numbers are still small compared with those following A-level/Scottish Higher qualifications. It is also unclear whether those achieving an IB diploma in the UK are more likely than those achieving the standard UK qualifications to enter HE in countries other than the UK.

4.3 Preparation for HE

4.3.1 What does HE want from the 14–19 education system?

The Nuffield Review of 14–19 Education and Training has recently reported on a series of focus groups with HE lecturers and admissions staff designed to investigate the types of knowledge, skills, attitudes and dispositions that they would ideally like to see being developed in new

Figure 4.6. A-levels and Scottish Highers achieved in physics in 2003 (left) and UK-domiciled first-year first degree students in related subjects in 2003/04 (right) (JCQ, SQA and HESA data).
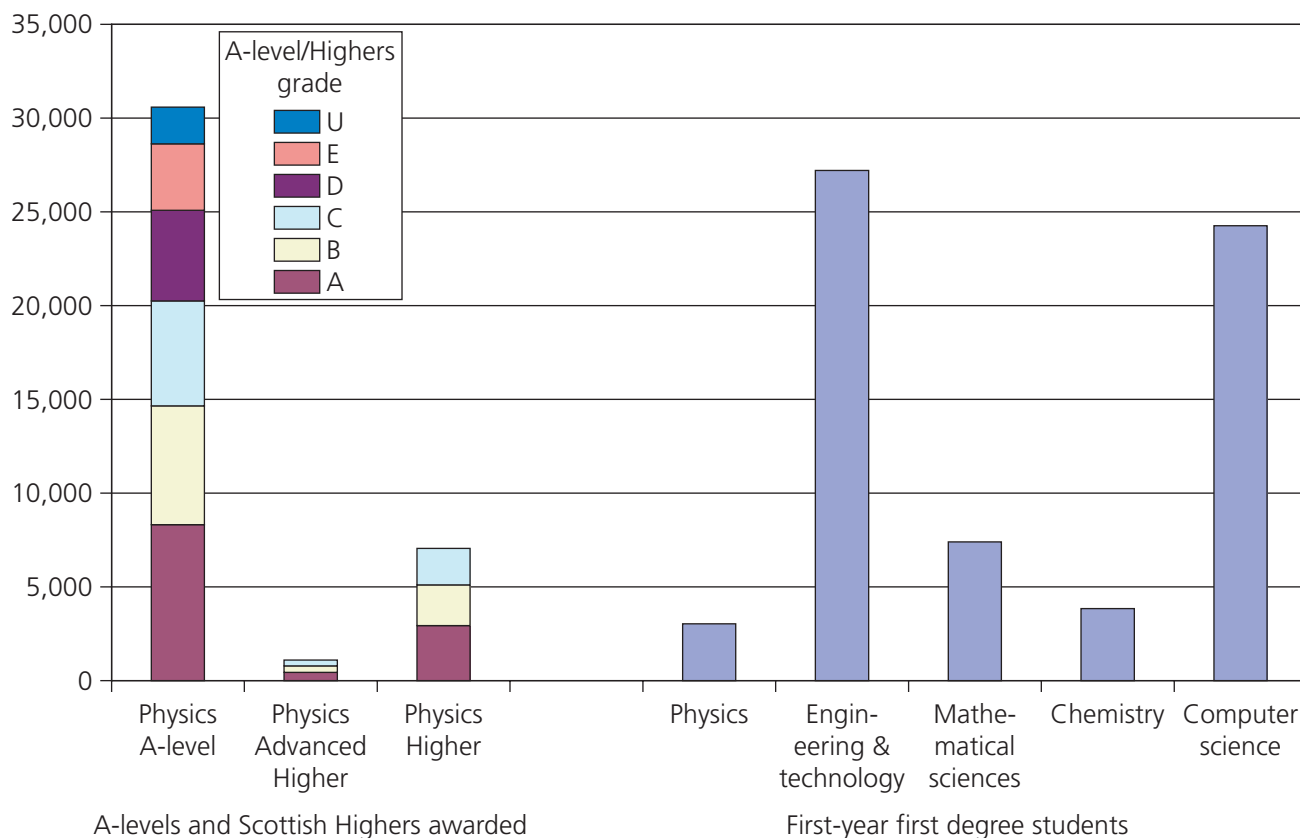
students through the 14–19 education and training system in order to provide a solid foundation for progression into, and success within, HE (Nuffield Review 2006).

The report found that what HE tutors are looking for is 'quite simple to state (but difficult to achieve in practice)'. The key attributes identified were: students who are committed to studying a subject, engaging critically with ideas, prepared to take some intellectual risks and able to use a range of skills to develop arguments.

The focus groups consulted all recognised that current students already possess several desirable traits, including the capacity to work hard and a broad range of social and problem-solving skills, in particular improved oral and presentation skills. However, there was broad agreement on several issues of concern. One of these was the reliance on narrow accountability based on exam success, which leads to learners coming into HE 'expecting to be told the answers' and valuable time being spent at the start of HE courses developing students' independent learning skills which could, to a certain extent, have already been developed. Another key message was that although choice and breadth within subjects are important, there are certain core areas in all subjects that need to be understood. In science subjects, a preference was expressed for students with a small core of mathematics concepts, especially in algebra, which could be reliably used, rather than a superficial knowledge of a larger amount of material. The question of students' mathematical skills is considered in more detail in 4.3.3.

4.3.2 Assessment and standards

Concerns are frequently raised about the perceived lowering of standards at A-level. In 2004, the A-level pass rate was 96%, and 22.4% of students received the top grade in at least one subject. Various explanations for achievement at different grades improving were outlined in the Nuffield Review Annual Report 2003–04 (Nuffield Review 2004). Although some explanations relate the improvements to more focused teaching and greater effort on the part of learners, others relate to the different modes of assessment: course work in addition to terminal examinations; the opportunity to repeat assessments to improve upon grades; more regular accumulation of assessments through modular systems; and the weighting given to the AS component of the full A-level. The report emphasises, however, that although over 22% of grades awarded were As, only 8% of candidates gained at least three grade As.

4.3.3 Mathematical skills

One of the more serious areas of concern we have identified is the level of mathematical skills with which students are starting STEM first degree courses. UK first degree science and mathematics degrees have traditionally assumed a significant amount of prior

knowledge from those starting courses and this has justified the shorter time to graduation (and minimum total time to completion of a PhD) than has been common in other countries. In particular, those starting physical sciences and engineering courses have been expected to have A-level or equivalent mathematics and good grades in the most relevant subject(s) to the course.

However, over recent years there have been complaints from universities that changes to the mathematics curriculum have resulted in students being less well prepared than previously in mathematics. A report by the Ove Arup Foundation (Ove Arup 2003), *Mathematics in the University Education of Engineers*, found that 'the problem of a gap between the expectations and reality of the mathematical competence of new undergraduate students has been a concern across all numerate degree subjects since the mid-90s'. In particular, the report noted that students are perceived to lack (i) fluency in algebraic manipulations, (ii) analytical powers for multi-step problems, and (iii) a proper appreciation of what mathematics is about in terms of the roles of precision and proof.

Although the report focused particularly on civil engineering, it had relevance for other degree courses with a significant mathematical content. Considering what mathematical knowledge was required by engineers, and how computer-based technology has changed the situation, the study concluded that mathematics was still a crucial component of a civil engineering course, although there had been a change in emphasis from mathematics for practical applications (which are now undertaken using computers) to mathematics to gain an underlying understanding of the systems being studied. The report observed that there may be a more profound problem for other branches of engineering such as electrical/electronic and aeronautical engineering, and physics, which use more abstract mathematical concepts than civil engineering.

More detail about the situation on the ground can be found in a report by the Engineering Council (Engineering Council 2000), *Measuring the mathematics problem*, which reports on a seminar, held in Cambridge in May 1999. At least 60 departments of mathematics, physics and engineering were at that time giving diagnostic tests in mathematics to their new undergraduates, and from these there was strong evidence of a steady decline over the 1990s of fluency in basic mathematical skills. There was also an increasing variation in the mathematical attainments and knowledge of students entering science and engineering courses, and reports from some universities that even students with A or B grade A-level mathematics could not be assumed to be competent in basic mathematical skills. The report recommended a wider take up of diagnostic testing as part of a two-stage process including prompt and effective follow-up to deal

with any individual weaknesses and those of the whole class cohort.

Concerns have also been voiced about the mathematical skills of students in the biosciences. The minimum mathematics qualification for many life science programmes remains a grade C at GCSE (Tariq 2004), although a significant minority of entrants to undergraduate life science courses, for example 19% of entrants in 2000, possess an AS level mathematics qualification. The situation is complicated by the fact that some students may be drawn to biological science subjects precisely because they perceive them to be less mathematical than other sciences. Therefore, any move to enhance the mathematics skills of undergraduates through compulsory courses could be unpopular with most students, and departments taking such steps may run the risk of losing potential students to other HE institutions (Goodfellow 2006).

Concerns over students' mathematical skills can be considered as two main issues: first a major concern over the fluency in basic mathematical skills such as basic algebra and the properties of basic logarithmic, exponential and trigonometric functions, and second a decrease in the level of advanced mathematics topics achieved by A-level students. Of these, the first is of fundamental importance and requires urgent investigation since, even if treated with special courses in the first year in HE, it severely reduces the confidence and motivation of students over the theoretical parts of the undergraduate curriculum. The second is considered further in the next chapter.

4.3.4 Bridging the mathematics gap: 16–19 to HE

It is clear that any action taken to improve the basic mathematical or other skills of new undergraduates takes time that would otherwise have been spent on the overall first degree curriculum. The pressure on available time within an undergraduate course has been further increased by a combination of the incremental nature of many STEM subjects and the fact that graduates are expected by both employers and the relevant learned society or engineering institution to graduate with a broad discipline background.

The introduction of four-year integrated masters courses in the physical sciences, mathematics and engineering has gone some way to alleviating the pressure on the undergraduate curriculum, although there are claims that a sizeable proportion of the extra time is required because of changes to the content of A-level syllabuses.

From a student perspective, it is highly demotivating to achieve the A-level or equivalent qualifications necessary to enter HE and then arrive and find that your level of knowledge is considered insufficient. Against a background of increasing student choice within the 14–19 curriculum and widening participation in HE, it is imperative that universities recognise the multiplicity of entry qualifications and subject combinations with which students are starting their courses and actively help students bridge the gap between 16–19 qualifications and degree-level study. The HE curriculum therefore needs to adapt to reflect changes in the 14–19 curriculum. In parallel with this, it is important for the HE community to articulate the skills, knowledge and experience that are perceived to be desirable in new undergraduates and to be involved, alongside other stakeholders including employers, in shaping the future development of 14–19 education.

5 STM first degrees: courses and students

This chapter is largely based on recast data commissioned jointly by the Society and the Office of Science and Innovation (OSI) from the Higher Education Statistics Agency (HESA). It considers STM first degrees to develop an overview of course provision, student numbers and the impact of department closures on regional provision. This chapter primarily concentrates on STM courses designed for professional scientists and technologists, as this was the area chosen to focus on in phase I, but other STM and engineering courses are included for comparison purposes.

Section 5.1 investigates available data on first degree STM course provision in terms of the number of HE institutions offering first degrees in science subjects and the distribution of students at different types of institution. Section 5.2 uses the new HESA data to develop time-consistent series of graduate numbers for the past decade and considers the position of four-year integrated masters courses within first degrees, the gender balance of graduates from STEM first degrees and trends in international student numbers on these courses.

Finally, section 5.3 discusses departmental closures and their impact on regional provision.

5.1 First degree STM course provision

5.1.1 HE institutions offering first degree STM courses

Since there are no official statistics on the number of universities offering first degree courses in science and mathematics, UCAS course listings for courses starting in October 2006 have been used as a measure of course provision. As in section 3.4.1, the university sector has been sub-divided. Again, this sub-division is not intended to imply any hierarchy or other value judgement of institutions: it merely acknowledges that differences exist within the university sector. The UCAS listings show that single honours courses in the sciences and mathematics are provided predominantly in the pre-1992 universities as shown in Figure 5.1. This is particularly true for four-year

Figure 5.1. The number of institutions offering first degrees in selected STEM subjects 2006 entry (UCAS).
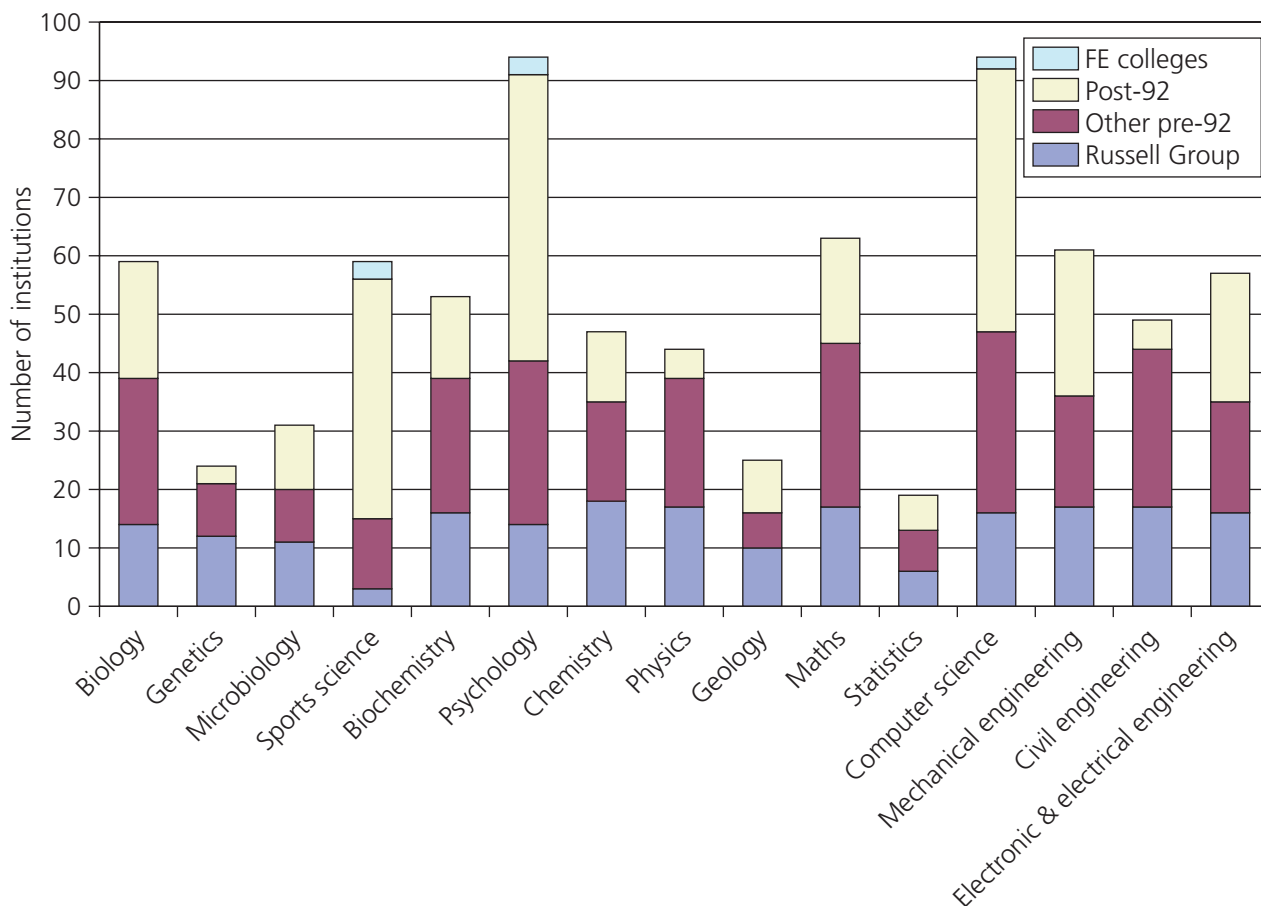
integrated masters courses (see Table A4.1 in Annex 4). However, despite closures and mergers of maths and traditional physical sciences departments in post-1992 universities, there remain some flagship courses in these institutions, often connected with local industrial clusters or more a vocational specialism. For example, almost 60% of analytical chemistry and pharmacy courses are at post-1992 universities.

The data also indicate the small number of institutions offering single honours first degrees in subjects such as statistics, geology and genetics. However, some institutions offer these subjects as part of joint honours degrees.

5.1.2 Distribution of STM students between institutions

Figure 5.2 shows that students studying for first degrees in the mathematical and physical sciences are concentrated in the pre-1992 universities, the distribution of biological sciences and engineering students between pre- and post-1992 universities is more equally balanced, while most computer science degrees are taken at post-1992 universities. These distributions have remained fairly constant over the past five years.

The predominance of computer science courses at post-1992 universities illustrates their proactivity in developing

new courses that play to their strengths, for example in more applied science and technology. In some cases, like forensic science courses, although these may have provided a satisfactory HE experience for the students, they appear to have been oversold on the vocational relevance of the qualification (SEMTA 2004).

More disaggregated data show a greater degree of variation between different subjects within the overall science groupings (see Table A5.1 in Annex 5). For example, 61% of physics degrees and 46% of chemistry degrees were studied at Russell Group universities, whereas 57% of degrees in forensic and archaeological science were studied at post-1992 institutions. Within the biological sciences, 32% of biology degrees were achieved at Russell Group institutions, 34% at other pre-1992 institutions and 34% at post-1992 institutions, whereas 75% of sports science degrees were obtained at post-1992 universities.

5.1.3 Variations over time

An indication of how the number of institutions making provision for teaching science subjects has changed over time can be obtained from data compiled by Universities UK (UUK) for its *Patterns of higher education institutions in the UK* report (UUK 2005a). The data in Figure 5.3 are extracted from that report and show the number of institutions in the UK teaching major science and

Figure 5.2. First degrees obtained by institutional grouping in 2004/05 (HESA 1997–2006c).
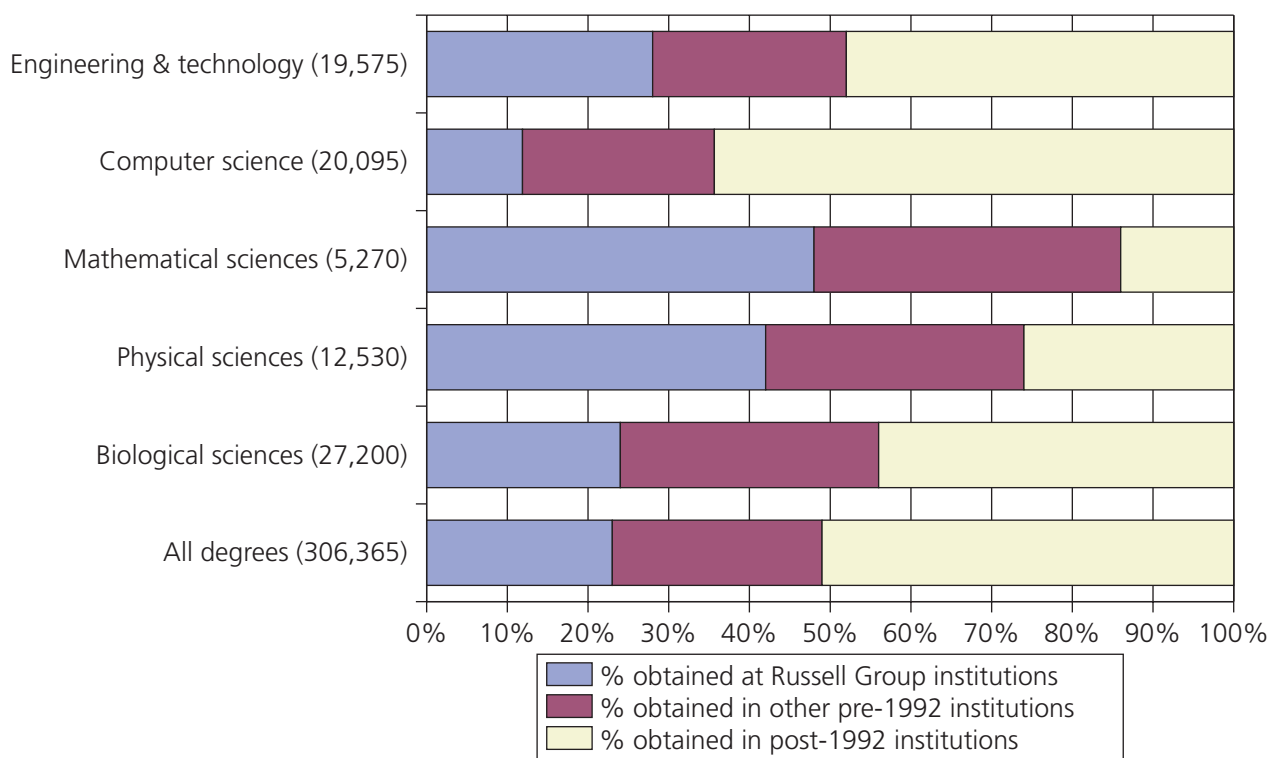
Figure 5.3. The number of institutions teaching science subjects, 1996/97 and 2003/04 (UUK 2005a), where institutions are confined to those teaching science subjects to 20 or more students for those subjects which in 2003/04 attracted more than 12,000 students (total of all undergraduates and postgraduates).
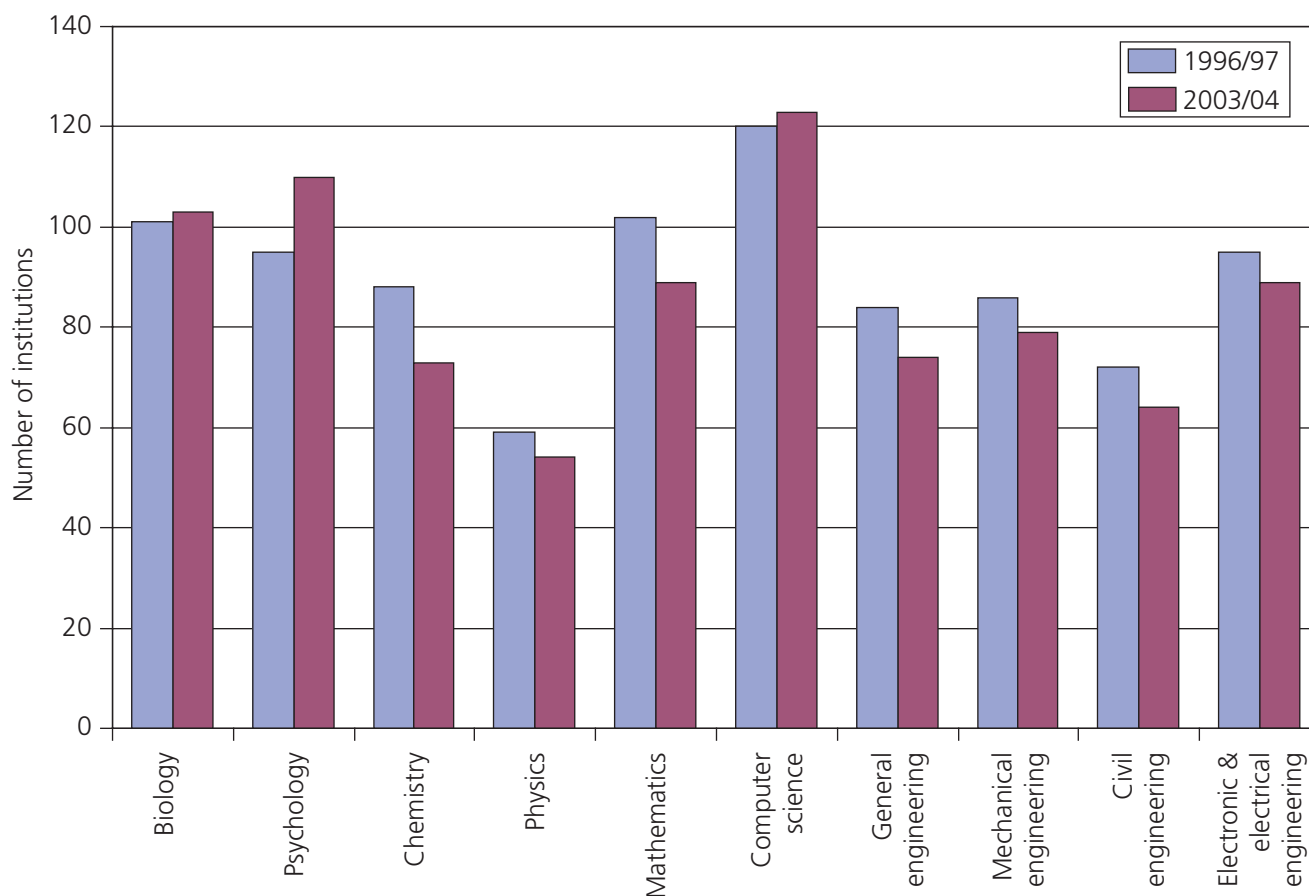
engineering subjects in 1996/97 and 2003/04 (at either postgraduate or undergraduate level). UUK have tried to ensure that the subject areas compared between the two years are as consistent as possible.

With the exceptions of computer science, psychology and biology, the number of departments teaching science subjects has decreased between 1996/97 and 2003/04. This issue is explored in more detail in chapter 5.3, which considers recent departmental closures in the sciences.

5.2 Trends in first degree student numbers in STM subjects

5.2.1 Consistent data series on student numbers

Trends in undergraduate participation in STM subjects are complicated; there are no simple headlines. Increasing overall participation in HE, year on year fluctuations in student numbers, changes in subject classifications and student categorisation, and the importance of looking at the trends in individual subjects not just subject categories all add to the complexity of the situation.

HESA is the official agency for the collection, analysis and dissemination of quantitative information about HE. Most analyses of trends in student and graduate numbers are based on data published by HESA in its annual *Students in HE institutions* volumes (HESA 1997–2006a), but there are several factors that make comparison of the data published by HESA difficult. In particular, there were major changes to the way in which students were counted and classified by subject of study from 2002/03 onwards.

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. The difference that these newly commissioned data make to apparent trends in science and maths subjects is discussed in Annex 6. From this, it is clear that the large apparent rise in student numbers in subjects such as maths and to a lesser extent biology are actually just the consequence of the change in the way that HESA have classified students on dual honours courses since 2002/03. The data presented in this chapter are based on the new set of HESA data. Further details of the subject categories and individual subjects used in the HESA classification system are also given in Annex 6.

5.2.2 STM first degrees within the first degree sector

A total of 270,000 first degrees were awarded to UK-domiciled students in 2004/05. Their distribution by subject area is shown in Figure 5.4.

In 2004/05, 21% of first degrees in the UK were awarded in the biological sciences, physical sciences, mathematical sciences or engineering and technology, compared with 22% in 1994/95. Adding computer science and subjects allied to medicine to these figures, 37% of first degrees in the UK in 2004/05 and 31% of first degrees in 1994/95 were awarded in the sciences.

One of the features of the expansion of HE has been the introduction of some popular science-orientated courses such as sports science and forensic science and the significant expansion of other subjects such as psychology. This has led to significant rises in the number of students taking subjects within certain groupings of subjects such as 'biological sciences' or 'physical sciences', which can mask stagnation or falls in more traditional subjects within these groupings. In developing policies in this area, it is important to be clear exactly what data are being used to support particular decisions.

Although the proportion of students studying for first degrees in the broad area of STM is encouraging, further disaggregation of these data reveals the differences between participation in different subjects and highlights the importance of looking in more detail than these broad HESA subject categories. For example, in 2004/05 the highest proportion of students graduating in the biological sciences category studied psychology (47%, up from 33% in 1994/95), and the second highest sports science (19%, up from under 10% in 1994/95) with biology students comprising 17% of the total compared with 31% in 1994/95.

Similarly, in 2004/05 in addition to chemistry (21%, down from 29% in 1994/95) and physics (19%, up from 18% in 1994/95), the physical sciences category includes 'forensic & archaeological science' (8%, from 2% in 1994/95). Table 5.1 disaggregates HESA data on graduations in the physical and biological sciences in 2004/05 to the principal subject level.

5.2.3 Trends in graduations from STM first degrees

This section investigates how the number of first degrees in science and maths obtained by UK-domiciled students has changed between 1994/95 and 2004/05. 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.

Figure 5.4. First degrees obtained by UK-domiciled students by subject area, 2004/05 (total first degrees obtained by UK-domiciled students, 270,180) (HESA data).
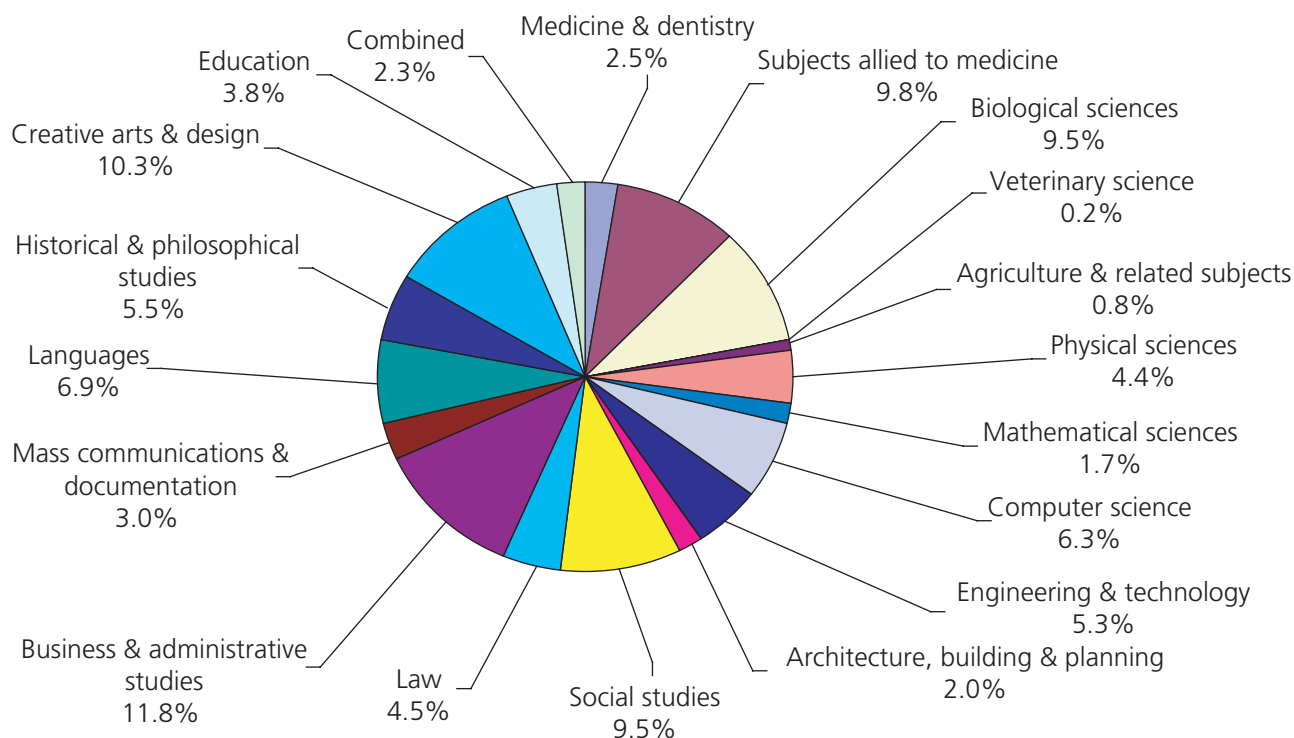
Table 5.1 First degrees obtained by UK-domiciled students in the physical and biological sciences by HESA principal subject, 2004/05 (HESA data)

First degrees obtained by UK-domiciled students, 2004/05	
Physical sciences	**11,780**
Broadly based programmes within physical sciences	250
Chemistry	2,530
Materials science	30
Physics	2,080
Forensic & archaeological science	720
Astronomy	280
Geology	1,130
Ocean sciences	200
Physical & terrestrial geographical & environmental sciences	4,050
Others in physical sciences	510
Biological sciences	**25,780**
Broadly based programmes within biological sciences	180
Biology	4,340
Botany	60
Zoology	870
Genetics	460
Microbiology	690
Sports science	5,520
Molecular biology, biophysics & biochemistry	1,610
Psychology	10,900
Others in biological sciences	1,150

Biology, chemistry, physics and mathematics

Figure 5.5 shows the trend in UK-domiciled graduations in biology, chemistry, physics and mathematics first degrees between 1994/95 and 2004/05. The data indicate that, despite fluctuations over this period, the number of UK-domiciled first degrees obtained in biology (between 4,000 and 4,500), physics (between 1,900 and 2,300) and mathematics (between 3,700 and 4,500) has been relatively stable. However, chemistry shows a 35% decline in graduates over the same period, with just over 2,500 graduates in 2004/05 compared with nearly 4,000 in 1994/95. It is also important to set these trends in the context of the over 20% increase in the total number of UK-domiciled first degree graduates over the same period. The year-to-year fluctuations in the data highlight the importance of considering trends in student numbers rather than simply changes between two dates.

Although Figure 5.5 gives a consistent view of subject trends, it is essential to note that because of the way in which HESA apportions students on joint or split programmes between subjects, these numbers do not represent the absolute number of students graduating in these subjects. Instead, the numbers will include a significant number of graduates who took joint subjects, predominantly initial teacher training (ITT) courses, and who were counted as a fraction of a person (this is discussed in further detail in Annex 6). Hence the numbers both under-represent the actual number of students who graduated with the subject as a significant part of their degree, and over-represent the actual number who

Figure 5.5. First degrees obtained in science and maths subjects by UK-domiciled students, 1994/95 to 2004/05 (HESA data).
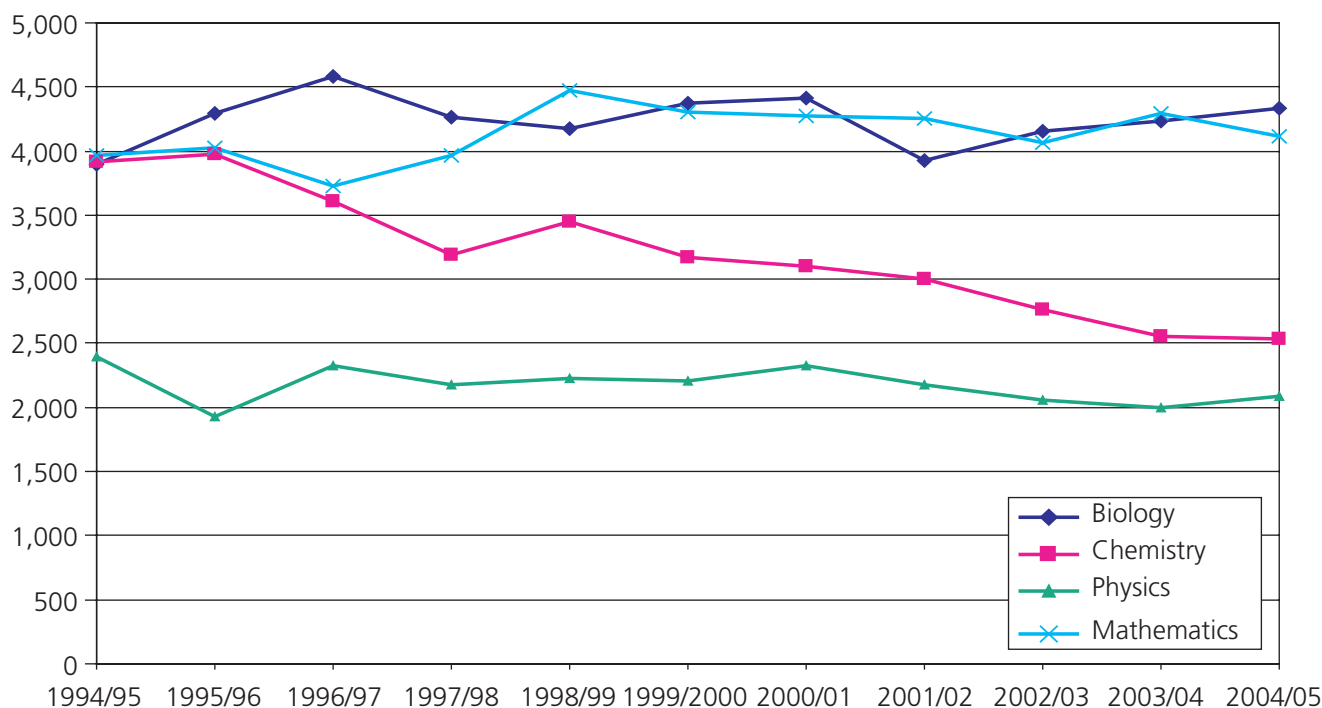
graduated with a single subject degree in that discipline. This effect appears to be most marked for mathematics.

Biological sciences

Figure 5.6 shows the trends in UK-domiciled graduations in the subjects classified in the HESA biological sciences category. This level of detail identifies both subjects with very low numbers of students, such as botany, and subjects whose student numbers have undergone large increases over this period, such as psychology.

Because of the changes in the HESA subject classification methodology between 2001/02 and 2002/03, several data lines have been constructed to maintain the most consistent data series possible. Annex 6 details the subject mappings that have been used. Most notably, before 2002/03 sports science was included within 'other biological sciences' and is likely to have contributed to the large growth of the latter category. Additionally, HESA had two separate psychology categories ('psychology not solely as a social science' and 'psychology as a social science') before 2002/03. As these were combined from 2002/03 onwards they have been added together to construct a continuous psychology line in this figure. In 2001/02, the last year for which separate figures are available, 'psychology not solely as a social science' represented about 6,200 of the 7,800 total psychology graduations.

Physical sciences

Data on physical sciences graduations over the same period are shown in Figure 5.7. Again, Annex 6 details the

subject mappings that have been used between 2001/02 and 2002/03.

Engineering and computer science

Similarly, Figure 5.8 shows how the number of first degrees in computer science and selected engineering subjects obtained by UK-domiciled students has changed between 1994/95 and 2004/05.

The broken line between 2001/02 data and 2002/03 indicates a change in the subject categories used by HESA which it was impossible to completely remove from the data. In particular, the 'electronic & electrical engineering' category has been created by adding two categories (electronic engineering and electrical engineering) which were separate before 2002/03. Despite these relatively minor inconsistencies in the data series, it is apparent that the number of graduates in computer science has dramatically increased over the past decade although their numbers appear to have decreased since 2002/03. First degree graduates in engineering subjects have remained reasonably stable over the period in question.

5.2.4 Recent trends in acceptances to STM first degrees

There have been some recent encouraging trends in acceptances to some STM subject courses. Table 5.2 shows UK-domiciled applications and acceptances to first degree courses since 2001. Each applicant to UCAS may make up to six applications to different courses and/or institutions (from 2000 applicants to medicine were

Figure 5.6. First degrees obtained in the biological sciences (by subject) by UK-domiciled students, 1994/95 to 2004/05 (HESA data).
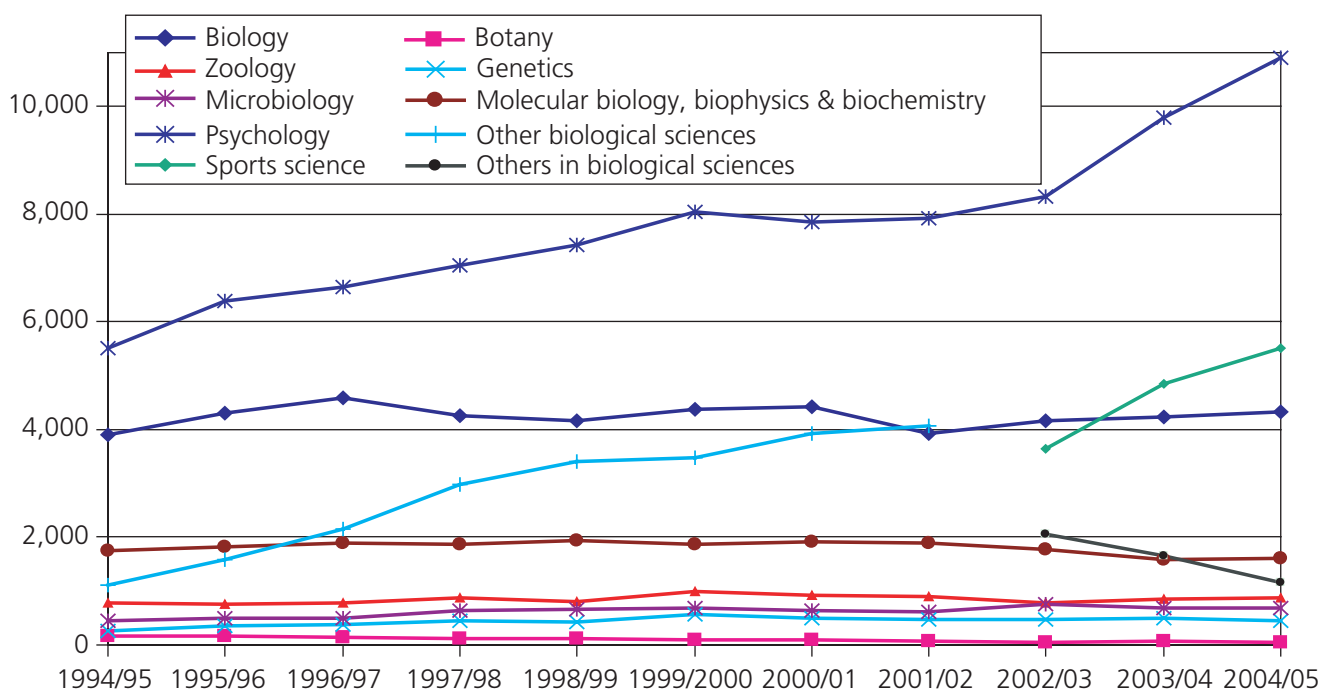
Figure 5.7. First degrees obtained in the physical sciences (by subject) by UK-domiciled students, 1994/95 to 2004/05 (HESA data).
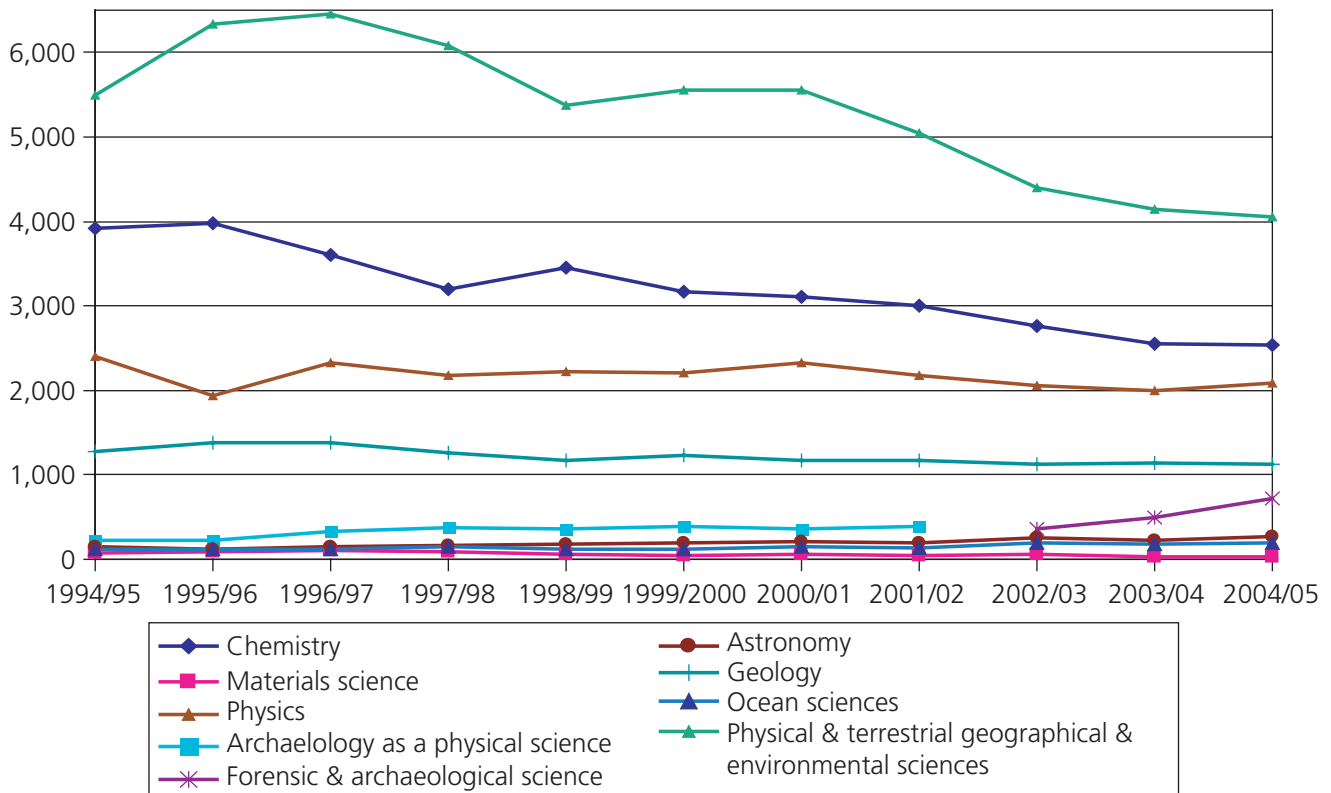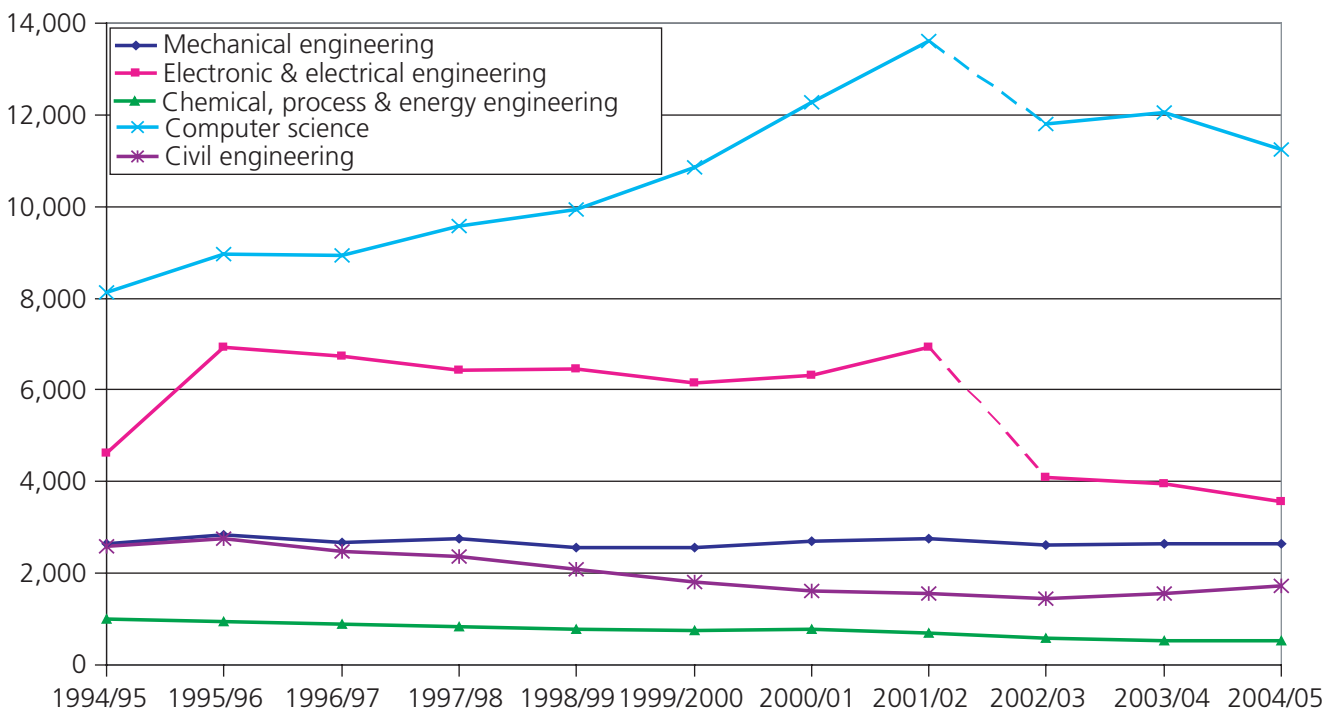

Figure 5.8. First degrees obtained in engineering and computer science by UK-domiciled students, 1994/95 to 2004/05 (HESA data).

limited to four applications and from 2001 entry this restriction also applied to dentistry and veterinary science applicants). Therefore the total number of applications is higher than the number of individual students who wish to study these subjects. Acceptances represent successful UCAS applicants. The numbers of accepted applicants are close, but not necessarily identical, to the numbers who actually enrol.

Acceptances to chemistry, mathematics and physics courses have increased over this five year period, while acceptances to biology courses have remained relatively stable. Both applications and acceptances have declined in engineering and, most notably, computer science.

Because it is difficult to relate 'applications' to 'acceptances' UCAS also provide a breakdown of 'applicants' which associates each applicant with the subject listed most frequently on their application form. It was noted in section 4.2.1 that every year since 1996 there have been more acceptances to chemistry than there have been applicants, and more recently the same has been true for biology, This indicates that several of these acceptances are for students falling back on their second or third subject choice, possibly having failed to obtain the grade required, for example in medicine, or entering HE through clearing. It is of note that for mathematics there have been more acceptances than applicants since at least 1994, but that this has never been the case for physics.

5.2.5 The four year undergraduate integrated masters courses

The introduction of four year integrated masters programmes in science and engineering subjects during the 1990s was motivated principally by the difficulty in fitting all of the work believed to be necessary in a first degree into the already very heavy workload required of STEM undergraduates. One of the objectives of this extra year of study was to better equip graduates to undertake professional STM careers. To qualify for the third and fourth years of the MSci course, students must achieve a satisfactory mark at the end of their second year of study, although not all of the eligible students elect to go onto the fourth year.

The number of students taking integrated masters courses (referred to as enhanced first degrees by HESA) has been reasonably stable over the past four years. In 2004/05 integrated masters courses still only represented 28% of chemistry, 30% of physics, 10% of mathematics and 28% of mechanical engineering first degree graduations (Figure 5.9). In the case of biology, the number of students graduating from integrated masters courses is very low (fewer than 30 in 2004/05) and seems unlikely to increase.

In the case of engineering, a BEng is no longer sufficient to achieve Chartered Engineering status; either an MEng or a free-standing masters degree is required. This has in effect downgraded the status of the bachelor degree. In the case of chemistry and physics, the BSc is still a sufficient education qualification for achieving Chartered status, although in the case of chemistry the Royal Society of Chemistry (RSC) only accredit four-year courses and graduates from three-year courses have to gain additional professional experience in order to achieve Chartered status. For some employers, for example in the pharmaceutical industry, an integrated masters degree is now a preferred minimum qualification for graduate employment.

Hence, although it may be difficult to fit this qualification into the Bologna process, other countries may also find that a three year course is insufficient for certain career options. In the UK, the fourth year of the integrated masters course is treated as an undergraduate course as far as student financial support is concerned, and hence

Table 5.2. Applications and acceptances for first degree courses by UK-domiciled students, 2001–2005 (UCAS data).

		2001	**2002**	**2003**	**2004**	**2005**
Biology	Applications	25,006	24,477	23,426	22,494	23,196
	Acceptances	4,571	4,640	4,442	4,250	4,486
Chemistry	Applications	16,129	15,385	14,906	15,618	16,990
	Acceptances	2,984	2,892	2,798	2,797	3,191
Maths	Applications	20,605	17,479	19,530	22,284	24,587
	Acceptances	3,698	3,379	3,700	4,091	4,533
Physics	Applications	14,475	15,639	15,952	14,106	15,725
	Acceptances	2,433	2,726	2,642	2,435	2,654
Computer Science	Applications	107,224	78,464	67,845	53,127	51,685
	Acceptances	20,547	15,281	13,751	11,732	11,356
Engineering	Applications	82,286	81,785	79,162	78,118	77,854
	Acceptances	16,896	16,840	16,098	15,505	15,532

they are generally significantly more attractive than free standing masters. The Research Councils have progressively withdrawn funding from taught masters in favour of MRes and PhD support.

5.2.6 Gender balance of STM students

The gender balance of students studying science subjects is not changing rapidly: female students remain in the minority in many physical science and engineering subjects. Figure 5.10 shows the gender balance of first degree graduates across the science, engineering and medicine subject categories in both 1994/95 and 2004/05. Whereas female first degree graduates are in the majority in subjects allied to medicine, the biological sciences, veterinary sciences and medicine and dentistry, they are clearly under-represented in the physical sciences and mathematics, and particularly in computing science and engineering & technology. For comparison, across all subject areas 57% of first degrees were obtained by female graduates in 2004/05.

Figure 5.11 shows the same data for selected individual subjects. The gender balance is noticeably worse in some subjects than others: in 2004/05, 8% of mechanical engineering first degree graduates and 21% of physics first degree graduates were female, compared with 48% of chemistry and 41% of mathematics first degree graduates. Whereas the gender balance has noticeably improved in chemistry and mathematics over the period from 1994/95 to 2004/05, it has increased very little in physics and very slightly decreased in mechanical engineering. However, in the case of chemistry the absolute figures are less positive. Overall student numbers are decreasing, but at a faster rate for men than for women: in absolute terms, there was a decrease in the number of women obtaining first degrees in chemistry between 1994/95 and 2004/05.

For 2004/05, the gender balance for the same subjects, disaggregated by three or four year (integrated masters) course is shown in Figure 5.12. In mathematics, it is noticeable that the proportion of female graduates from the four year course is lower than that from the three year course. Without knowing the intentions of students at the start of their degree course, it is not possible to say whether the decision to study for a three year degree is made before entering university or during the first two

Figure 5.9. The balance between three and four year first degrees in selected science and engineering subjects, 1994/95, 1999/2000 and 2004/05.

Figure 5.10. First degrees obtained by UK-domiciled students in selected STEM subject areas by gender, 1994/95 and 2004/05 (HESA data).
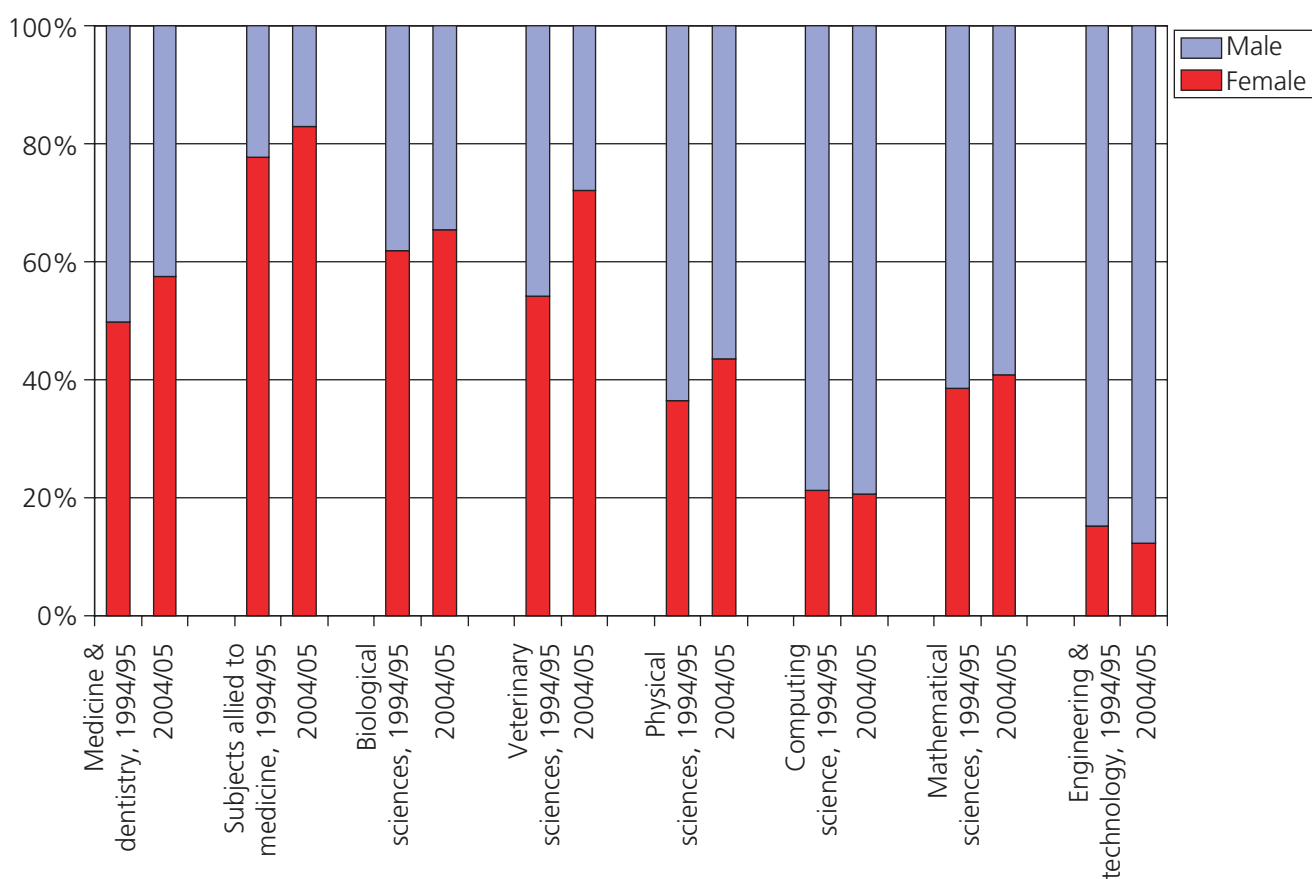
years of study. Without further investigation it is also impossible to determine why this decision is made and what impact it has on future career choices.

5.2.7 International student trends

HESA data can also be used to investigate how the non-UK-domiciled proportion of first degree graduates has changed over time. Of the 237,698 first degree graduates in 1994/95, 92.5% were UK-domiciled, 3.1% were domiciled elsewhere in the EU and 4.4% were of non-EU domicile. In 2004/05, there were 306,364 first degree graduates, 88.2% UK-domiciled, 4.5% domiciled elsewhere in the EU and 7.3% of non-EU domicile.

Figure 5.13 shows the domicile of first degree graduates for all first degrees and for first degrees in selected science and engineering subjects in both 1994/95 and 2004/05. For both years, in biology, chemistry, physics and maths the proportion of UK-domiciled first degree graduates is higher than the proportion of first degrees awarded to UK-domiciled students across all subjects. However, in civil and mechanical engineering the situation is reversed, with more graduates than the average across all subjects of non-UK-domicile.

The situation at first degree level is notably different from that at the postgraduate level (Figure 2.3) where the percentage of masters degrees awarded to UK-domiciled students has decreased from 68% in 1994/95 to 48% in 2004/05, and the percentage of PhDs awarded to UK-domiciled students has decreased from 67% to 61% between the same years, although the absolute number of UK-domiciled graduates has increased over this period.

5.3 Departmental closures and their impact on regional provision

Science provision can be considered at a range of levels – EU-wide, UK-wide, by country or by region. To some students and large firms the location of a particularly attractive university course or research programme is irrelevant. However, the advent of a mass HE system, the reduction in individual student support, and the imperative to provide equal opportunity of access to HE mean that local teaching provision is very important. The formation of regional 'deserts' created by closures of university departments increases the risk of discrimination against those who may need to stay near home because of family commitments, cultural or financial pressures.

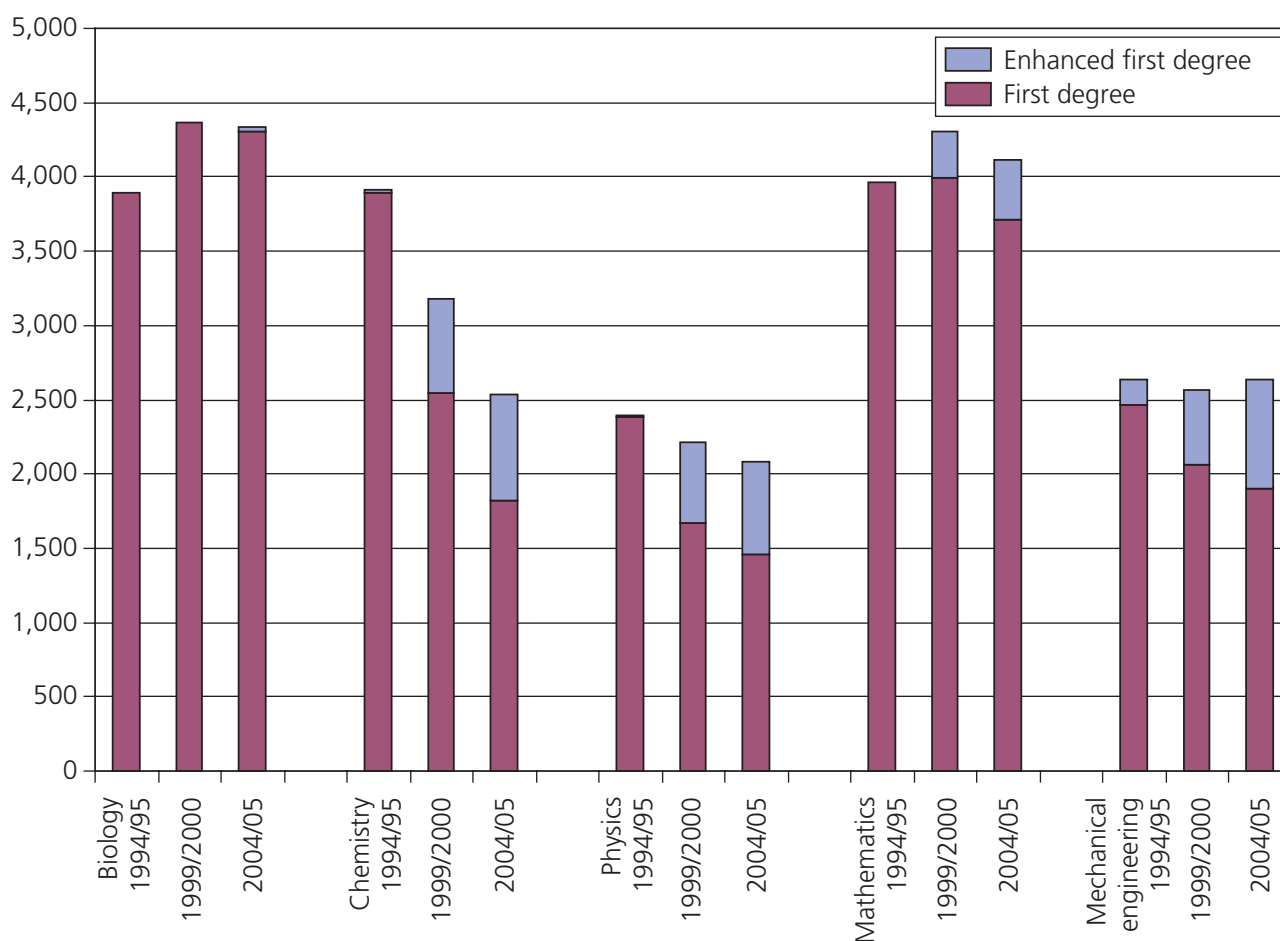Figure 5.11. First degrees obtained by UK-domiciled students in selected subjects by gender, 1994/95 and 2004/05 (HESA data).
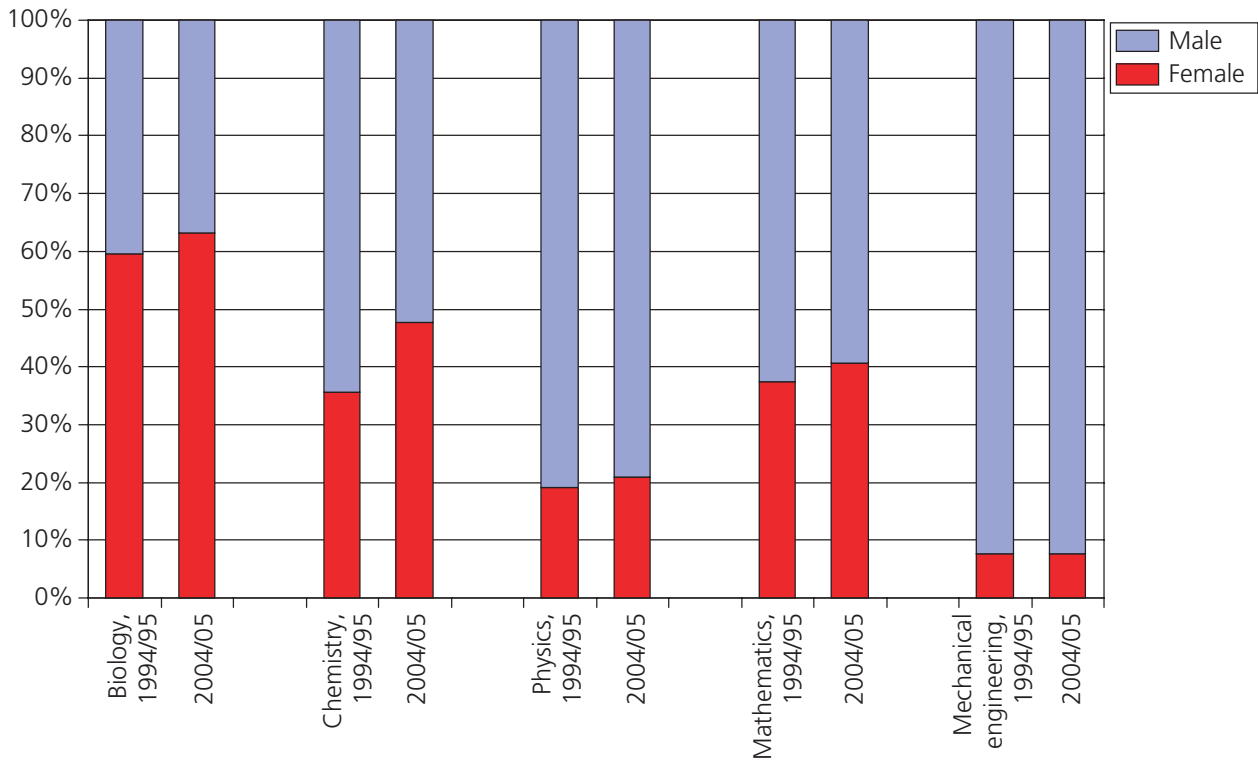
Figure 5.12. Three year first degrees and four year (integrated masters) first degrees obtained by UK-domiciled students in selected STEM subjects by gender, 2004/05 (HESA data).
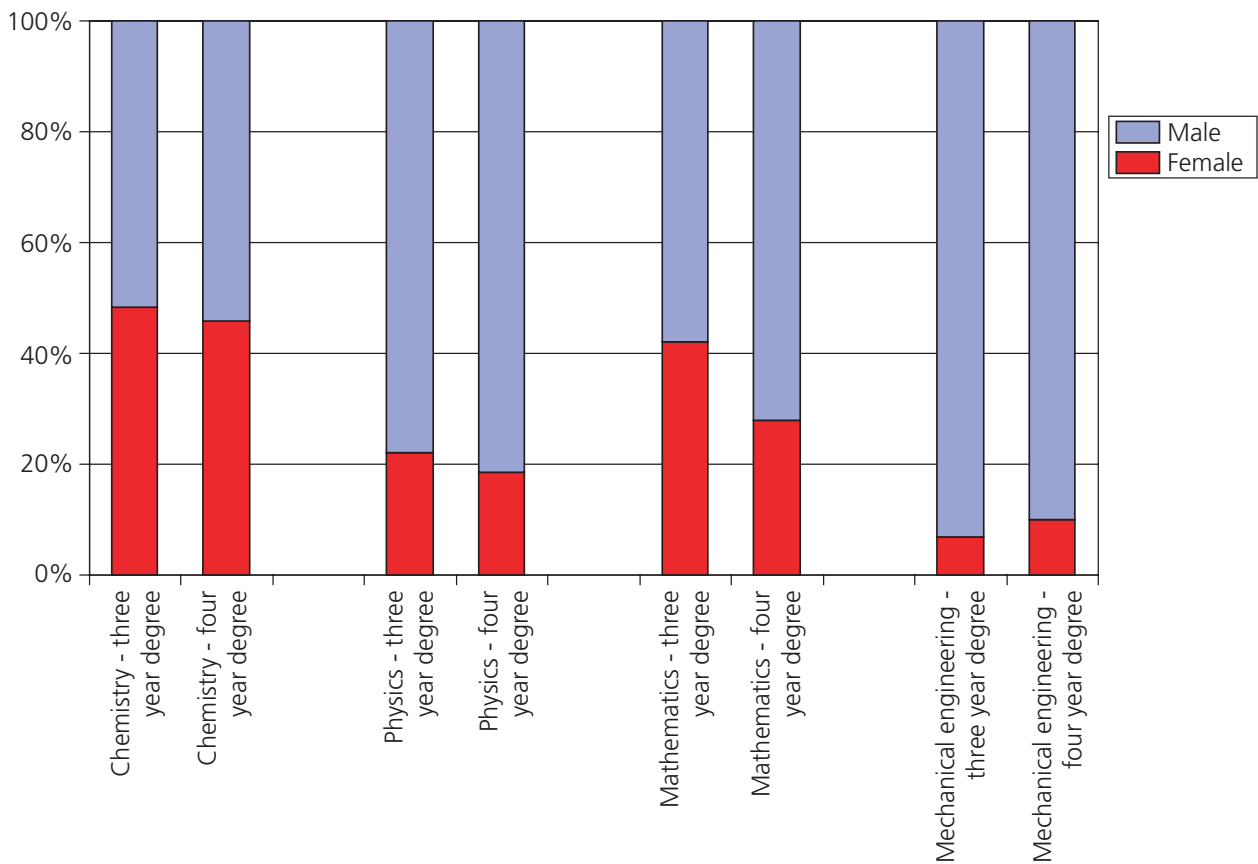
Figure 5.13. First degree graduates in selected science subjects by domicile (UK, other EU and non-EU), 1994/95 and 2004/05 (HESA data).
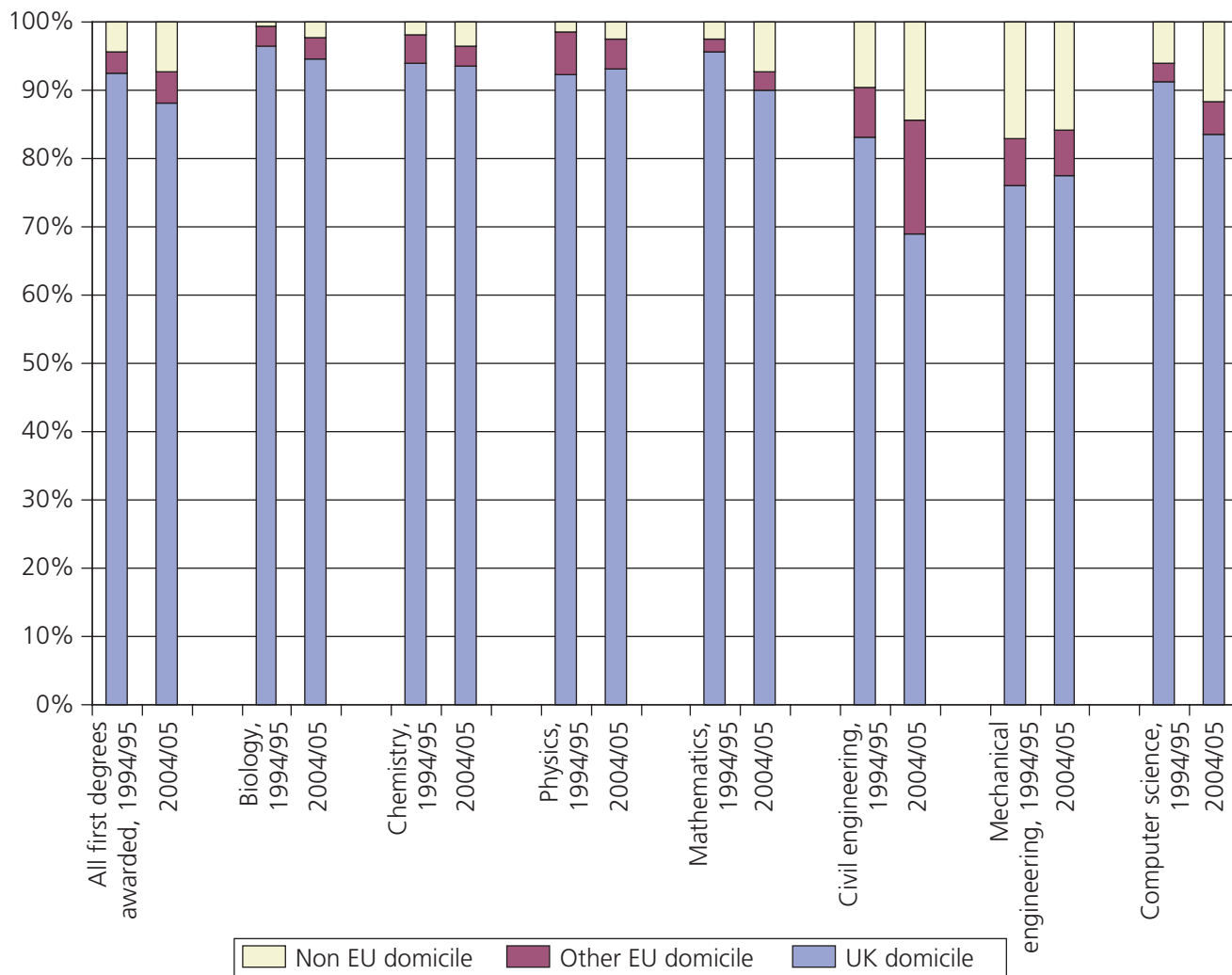
Furthermore, without local university departments in the physical sciences and engineering, the opportunities for increasing university–school links in these subjects, as promised in the Government's science and innovation investment framework (HMT 2004), will be severely reduced in some areas.

Although larger companies can access information on a worldwide basis, small and medium-sized enterprises (SMEs) can be very dependent on their local universities. Hence, it is still relevant to consider what provision is required at least to the level of the English regions.

The science and innovation investment framework (HMT 2004) states that approximately 15 physics and 11 chemistry departments have closed over the past ten years, based on data from several sources including the research assessment exercise (RAE) and UCAS. The Institute of Physics in evidence to the House of Commons (House of Commons 2005) has found that, since the removal of the binary divide in 1992, 30% of university physics departments have either merged or closed.

Recent high-profile withdrawals of undergraduate teaching have occurred at the Universities of Reading and Newcastle, rated 4 in the 2001 RAE.

The RSC (House of Commons 2005) identifies 17 closures or mergers of chemistry departments between 1996 and 2001 (based on RAE submissions) – 14 of these 17 departments were rated 1 or 2 in the 1996 RAE. Interestingly, no departments rated over 3a in the 1996 RAE closed before the 2001 RAE, but the closures since 2001 have been in higher-rated departments:

- Queen Mary, London   3a rated in 2001 RAE

- Kings College London   4 rated in 2001 RAE

- Swansea University   4 rated in 2001 RAE

- Exeter University   4 rated in 2001 RAE

More recently, the Chemistry Department at the University of Sussex came close to closure, reportedly because the university was concerned that might not

retain its 5 rating in the 2008 RAE. This threat appears to have been lifted, and applications are reported to be buoyant.

Universities have always been autonomous institutions and their independence is a key strength of the UK HE system. The structure of individual universities is not immutable, and the Society has indicated (Royal Society 2005) that it is not necessarily opposed to the closure or merger of science departments where the change can be justified in terms of improving the overall science provision locally, regionally and nationally, and provided the welfare of existing students is safeguarded. However, it registered concern that some examples of closures did not apparently fulfil these conditions. Considering recent closures, HEFCE's claim that they were merely a demand-side problem appears far too simplistic at the local level, although there is clearly a wider issue of whether sufficient young people are being attracted to university physical science, mathematics and engineering courses.

It should be observed that enrolments on some science and engineering courses, particularly in the biological sciences, have increased and this is to be welcomed. However, such rises do not necessarily offset the significance of the falls in other subjects, such as physics and chemistry. As discussed in section 5.2, it is also important to consider individual subjects (rather than the larger subject categories) – for example, although overall numbers in the biological sciences have risen, the number of students obtaining first degrees in biology has remained relatively stable over the past decade (Figure 5.5).

The House of Commons Science and Technology Committee considered the issue of strategic science provision in English universities in a 2005 inquiry (House of Commons 2005), recommending that the Government should encourage a collaborative model in which universities work in regional partnerships or clusters to provide STEM teaching provision at undergraduate level. This could be one possible way of ensuring that core science and engineering courses are available at a regional level as long as this was organised at a local level and not imposed as a top-down model.

Following concern over the closure of departments, HEFCE has introduced a programme of support for strategically important and vulnerable subjects, including STEM and modern foreign languages. Vulnerability is being measured by either a mismatch between the supply of potential students for HE and employer, government or other demand, or by a concentration of the subject in institutions which may be particularly vulnerable to change. As part of this, the programmes designed to both increase and widen participation in STEM subjects have been developed in collaboration with the relevant professional bodies and communities and in engineering, physics and chemistry and similar programmes are being developed in mathematics and computing.

6 What do STM first degree graduates do?

In this chapter the first destinations of graduates from STM first degrees are explored using new data commissioned jointly by the Society and the Office of Science and Innovation (OSI) from the Higher Education Statistics Agency (HESA).

Section 6.1 introduces the HESA first destinations data and investigates graduate destinations in terms of employment, further study or unemployment. Section 6.2 then explores further those STEM graduates entering employment through the industrial sectors in which they are employed and the type of work that they are doing. Finally, section 6.3 considers the available data on those STM first degree graduates who are undertaking further study.

6.1 The HESA first destinations survey

6.1.1 Graduate first destinations methodology

All UK-domiciled graduates receive a questionnaire from their university or college six months after they have graduated. This questionnaire, designed by HESA, asks about what activities the graduate is involved in at that time, focusing on their occupation in terms of employment and further study, training or research. Although useful as a short-term indicator of graduate employment prospects, no longer-term follow-up work is undertaken at present. However, HESA is planning longitudinal follow-up surveys on a sample basis approximately three and a half years after graduation. A pilot survey was carried out in the winter of 2005/06 on a test sample from the 2002/03 leaving cohort. The results from this will not be published, but it will inform the design of the first full survey from the same cohort planned for 2007.

As for the student numbers statistics presented in Chapter 5, there are several factors that make time-series comparison of the first destinations data published by HESA difficult, in particular changes in the way in which graduates were counted and classified by subject of study from 2002/03 onwards. Additionally, until 2001/02, first destination information was only collected from students whose study had been full-time (including sandwich students) but from 2002/03 leavers from part-time programmes were also surveyed.

The joint Royal Society and OSI revised set of data from HESA for the period 1994/95 to 2004/05 again remove as many of these discontinuities as possible. Because data for graduates who studied part-time are unavailable before 2002/03, this chapter only considers the destination of graduates who studied full-time. As with the data presented in chapter 5, some relatively minor discontinuities remain, and these are considered in more detail in Annex 6.

In considering the implications of these first destination statistics, it is essential to bear in mind that they only provide a snapshot of destinations six months after graduation. The value of this snapshot as a longer-term indicator of career is limited. The second-phase data, which HESA plan to collect three and a half years after graduation, should provide an interesting source of information on the early stages of graduate careers, but again this will be a relatively short-term view. There are some cohort studies, which provide a longer-term view, but these are all either limited in extent, or not easy to disaggregate into separate science disciplines. These studies are considered in section 7.2.

6.1.2 Employment, further study, unemployment

The graphs set out in Figure 6.1 show the percentage of UK- and EU-domiciled first degree graduates from full-time programmes for selected science subjects who, approximately six months after graduation, have entered employment, are undertaking further study or training, are unemployed, are not available for employment, or are doing something else. First degree graduates from all subjects have been included for comparison purposes. It should be noted that those who have not returned their questionnaire and are therefore of unknown destination are not included in this figure. The non-return rate varies by subject and year, but is usually between 15% and 20%.

The percentage of science and engineering graduates entering employment has remained relatively unchanged between 1994/95 and 2003/04, ranging between 37% (physics) and 72% (computer science) in 1994/95 and between 42% (physics) and 65% (computer science) in 2003/04.

Those graduating in chemistry, physics, mathematics or biology are more likely to undertake further study or training than those graduating in engineering & technology subjects or the computer sciences. This trend seems to largely explain the difference in the percentages of science graduates and engineering & technology graduates entering employment. In 2003/04, 33% of physics graduates, 34% of chemistry graduates, 24% of maths graduates and 23% of biology graduates were participating in further study or training, compared with 15% of engineering & technology graduates, 12% of computer science graduates and an average of 16% for all graduates.

The percentage of graduates who are recorded as unemployed about six months after graduation has decreased slightly in most science subjects between 1994/95 and 2003/04, and is small compared with the percentage of graduates working and studying. However, it is interesting to note that in 2003/04 graduates from

Figure 6.1. First destination of full-time UK- and other EU-domiciled first degree graduates for selected STEM subjects, 1994/95 and 2003/04 (HESA data). Figures in brackets represent the number of graduates who have responded to the HESA first destinations survey.
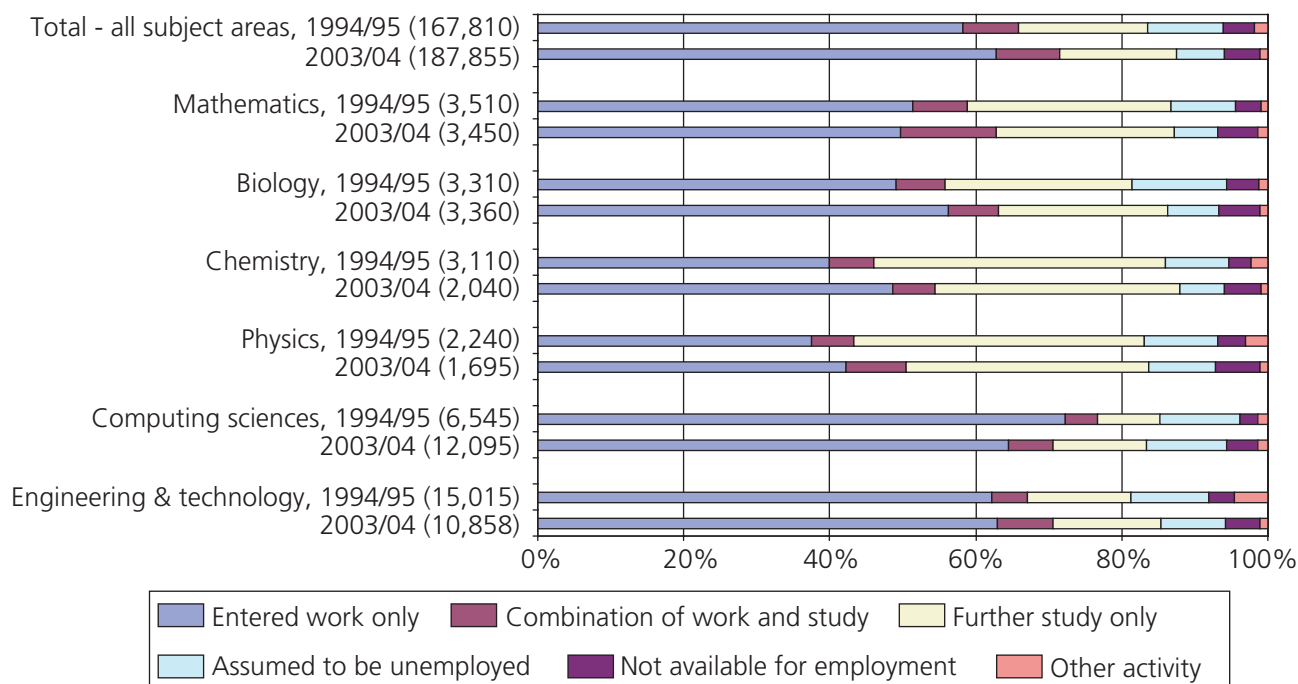
some science subjects seem more likely to be unemployed than the average graduate. For example, in 2003/04, 11% of computer science graduates, just under 9% of engineering & technology graduates and just over 9% of physics graduates were unemployed, compared with an average of 7% for graduates from all subjects. The time scale of the survey could mean that this is a short-term effect, with science graduates taking longer than graduates in some other subjects to find a job.

For 2003/04 the data have also been split by those who completed three-year first degrees and those who completed four-year enhanced first degrees (integrated masters courses). Figure 6.2 illustrates that there are clear differences in destination patterns, with those graduating from four-year mathematics, chemistry and physics courses less likely than graduates from three-year courses to enter employment and more likely to enter further study. In computing sciences and engineering and technology, graduates from four-year courses are slightly more likely than graduates from three-year courses to enter employment directly. In the case of computer science, and to a lesser extent some other subjects, any interpretation of the data should take account of the small numbers involved with the four year courses.

Section 6.2 explores those graduates entering employment, in terms of the sector in which they are working and the type of work that they do, while section

6.3 investigates the available data on those graduates who undertake further study after a STEM first degree.

6.2 Where are graduates employed and what type of work are they doing?

A breakdown of the destinations of graduates entering employment is provided by Standard Industrial Classification (SIC) and by Standard Occupational Classification (SOC). These two classifications give information about the type of economic activity the business employing the graduate is engaged in, and both the kind of work performed by the graduate and the skill-level required for the competent performance of the tasks and duties.

6.2.1 Graduate destinations by Standard Industrial Classification

The UK Standard Industrial Classification of Economic Activities (UK SIC(92)) is used to classify business establishments and other statistical units by the type of economic activities they are engaged in. The SIC is broken into seventeen main sections, such as 'manufacturing', 'construction', 'financial activities' and 'health & social work', each of which then branches into finer levels of detail.

Figure 6.2. *First destination of full-time UK- and other EU-domiciled three year first degree and four year first degree (integrated masters) graduates for selected STEM subjects, 2003/04 (HESA data). Figures in brackets represent the number of graduates who have responded to the HESA first destinations survey.*
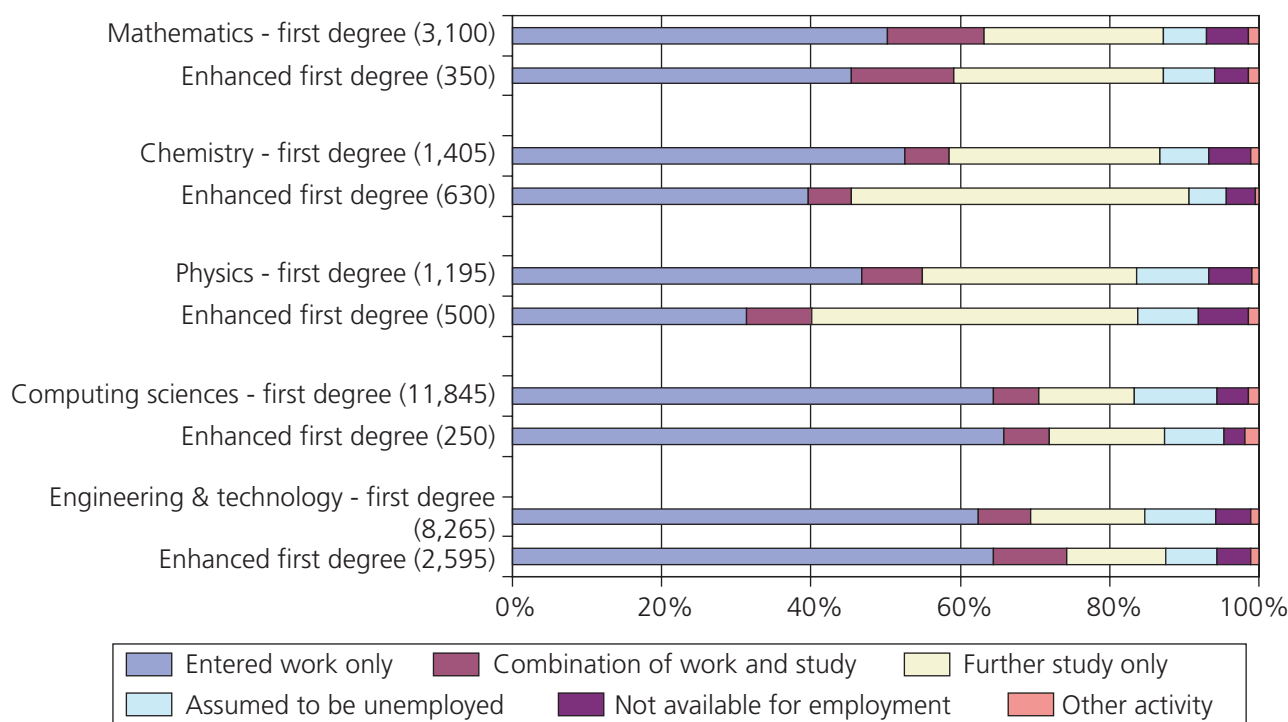
SET for success (Roberts 2002), the report of the Roberts Review into the supply of people with STEM skills, used an analysis of graduate first destinations by SIC to illustrate that 'in many science and engineering subjects over half of all new graduates enter employment working in "R&D manufacturing" '. This analysis was based on creating an 'R&D manufacturing' category by combining the SIC categories for 'manufacturing' and 'real estate, renting and business management', with the latter category assumed to be primarily R&D. However, the latter category includes sub-categories such as 'other business activities' covering employment in sectors such as accountancy and management consultancy, which are likely to attract significant numbers of science graduates, as well as sectors such as the law and advertising. The reworked HESA data show that fewer STM first degree graduates are entering manufacturing and R&D than thought in *SET for success*, the numbers are, however, still significant, especially in chemistry and engineering. Furthermore an important route for such professional jobs is through a higher degree.

Since looking at trends in subject areas in aggregate (for example, biological sciences) can mask quite disparate trends in individual subjects, an analysis of graduate destination by SIC for individual science subjects has been carried out for 1994/95 and 2002/03. The SIC categories considered have been chosen to reflect the sectors which STEM graduates enter in the largest numbers; SIC categories which attract fewer STEM

graduates have been amalgamated in to the 'other' category.

Figure 6.3 shows the first destination of those graduates entering employment only and those doing a combination of work and further study by SIC for 1994/95 and 2002/03. As described in Annex 6, HESA count students and graduates from secondary Initial Teacher Training (ITT) first degrees as one half weight in the 'teacher training' subject category and one half weight in their subject specialism. This apportionment of ITT graduates between 'teacher training' and their specialist subject accounts for the majority of graduates who enter the 'education' SIC direct from a first degree (in contrast, graduates from STEM courses who wished to enter teaching would first have to complete a postgraduate certification in education (PGCE) course and would therefore appear in the further study category in Figure 6.1 six months after graduation). However, the number of ITT graduates in each subject line, such as mathematics, are only half the number of ITT graduates with a specialisation in that subject since they are apportioned using a 50:50 split between 'teacher training' and their specialist subject.

Key points to note are:

* The decline in the proportion of graduates entering employment in manufacturing industry between 1994/95 and 2003/04, which is particularly marked in chemistry (37% in 1994/95 to 27% in 2003/04),

Figure 6.3. First destination of full-time UK- and other EU-domiciled first degree graduates by Standard Industrial Classification for selected STEM subjects, 1994/95 and 2003/04 (HESA data). Figures in brackets represent the number of graduates who have responded to the HESA first destinations survey.
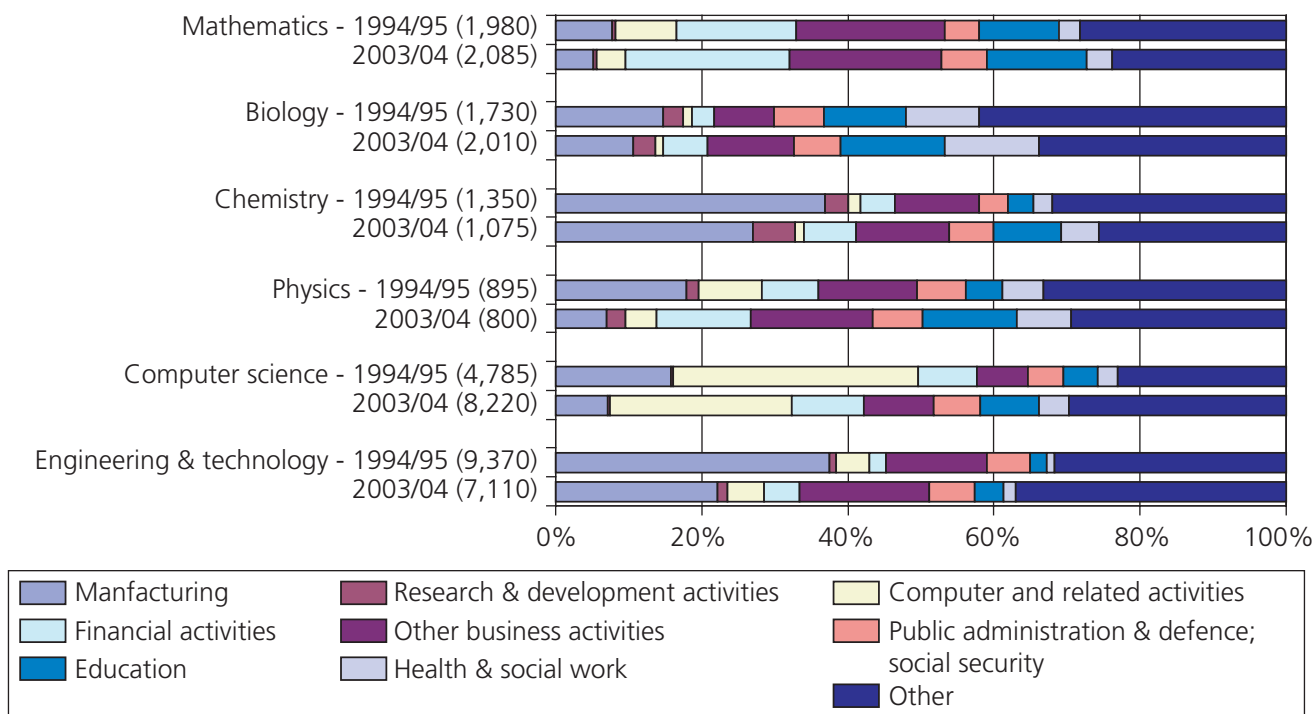
engineering & technology (38% in 1994/95 to 22% in 2003/04) and physics (18% in 1994/95 to 7% in 2003/04).

- The very small proportion of graduates entering employment in businesses classified in the R&D sector (for 2003/04, 6% in chemistry, 3% biology and physics, and 1% in engineering & technology).

- The relatively large proportion of STEM graduates entering employment in the financial and other business activities sectors (including areas such as accountancy, management consultancy, law and advertising): in 2003/04, 43% of maths graduates, 18% of biology, 20% of chemistry, 30% of physics, 20% of computer science and 23% of engineering & technology graduates entered employment in these two categories. In all cases, this was an increase on the proportion of graduates entering these areas in 1994/95. This last point indicates the continual demand for numerate graduates to enter employment in these areas.

- The increase in those entering 'education', largely those graduating from secondary initial teacher training courses with a STM specialism.

For 2003/04, the data have also been split by those who completed three-year first degrees and those who

completed four-year enhanced first degrees or integrated masters. Figure 6.4 show that there are significant differences in the employment patterns between these two groups in some subjects.

It is clear that chemistry, physics and engineering & technology graduates who have undertaken an integrated masters course are more likely to enter the manufacturing sector than those who have graduated from a three year degree. Similarly, a higher proportion of integrated masters graduates in computer science than graduates from three year degrees in computer science enter employment in a business associated with computer and related activities. This would suggest that graduates from integrated masters courses are more likely to be seeking work in an area related to their degree subject. Interestingly, graduates from integrated masters courses in maths are more likely to enter employment in financial or other business activities than graduates from three year maths degrees.

It is, however, important to remember that although the proportion of integrated masters graduates entering a certain sector may be larger than the proportion of graduates from three year courses, the absolute numbers graduating from integrated masters courses are smaller, and in computer science very much smaller.

Figure 6.4. First destination of full-time UK- and other EU-domiciled three year first degree and four year first degree (integrated masters) graduates by Standard Industrial Classification for selected STEM subjects, 2003/04 (HESA data). Figures in brackets represent the number of graduates who have responded to the HESA first destinations survey.
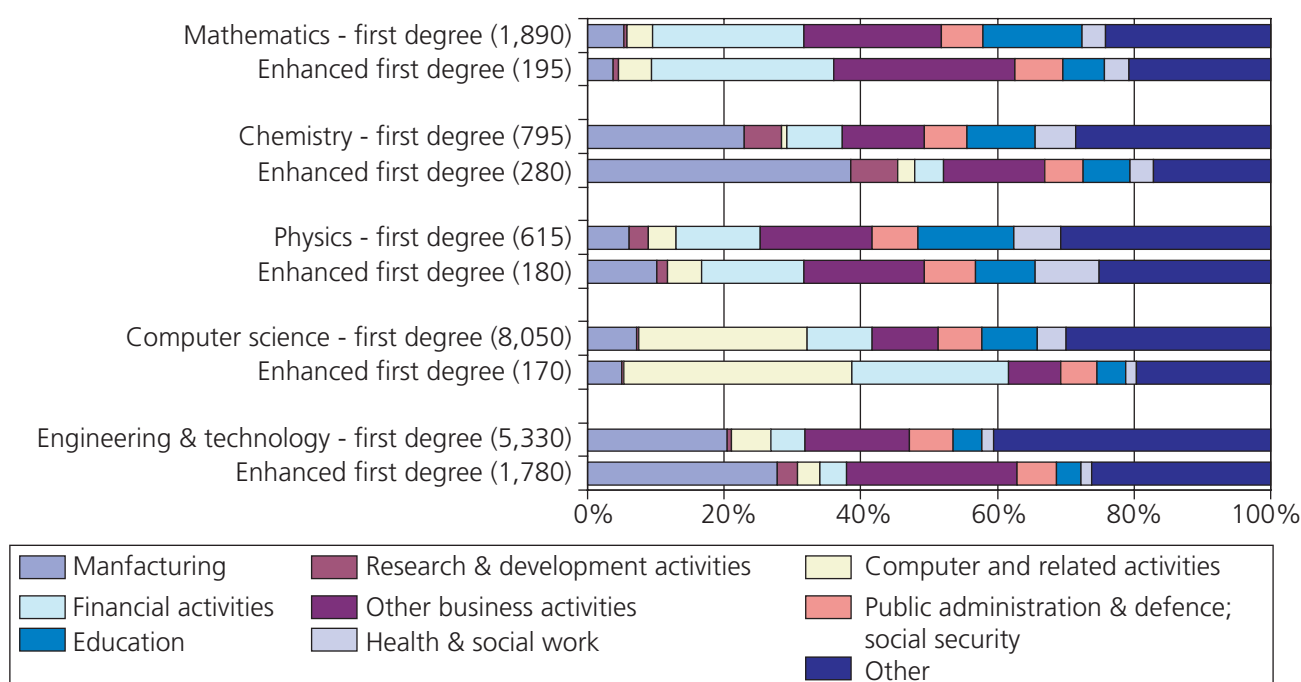
6.2.2 Graduate destinations by Standard Occupational Classification

The Standard Occupational Classification (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). Because of changes in the SOC variant used by HESA, the exact categories have changed between 1994/95 and 2002/03 and the data are not directly comparable.

Occupations are classified under SOC groups using indexing terms, which usually describe the job, and qualifying terms, which make the job title specific. The classification is dependent on the level of detail provided about the job by the graduate filling in the HESA first destinations survey. It seems that research scientists could be recorded as either 'science professionals' or 'research professionals'. However, the 'research professionals' category is not disaggregated further by HESA and includes social science researchers and researchers not otherwise classified. Therefore, although the occupational information provided by the SOC is useful, it is impossible to completely isolate those graduates who are working as professional scientists.

Figures 6.5 and 6.6 show the first destination of those graduates entering employment only and those doing a combination of work and further study by SOC for 1994/95 and 2002/03 respectively.

Key points to note are:

- The number of graduates classified as science and engineering professionals varies significantly by subject with 35% of engineering & technology and 20% of chemistry graduates classified under this heading in 2003/04, compared with 6% of biology and 7% of physics graduates.

- Graduates in highly numerate disciplines such as engineering & technology, mathematics and physics are more likely than graduates from disciplines such as chemistry and biology to be classified as information & communication technology (ICT) professionals. Not surprisingly, graduates from computer science degrees are the most likely to be working as ICT professionals, with 28% in this category six months after graduation.

- 12% of chemistry, 9% of biology and 4% of physics graduates are classified as science and engineering technicians, compared with only 2% of engineering & technology graduates and 1% of computer science graduates.

- Assuming that the seven 'professional' categories constitute 'graduate-level' jobs then 45% of engineering & technology graduates and 38% of chemistry, 37% of mathematics and 35% of computer science graduates, 33% of physics graduates and 20% of biology graduates are

Figure 6.5. First destination of full-time UK- and other EU-domiciled first degree graduates by Standard Occupational Classification for selected STEM subjects, 1994/95 (HESA data).
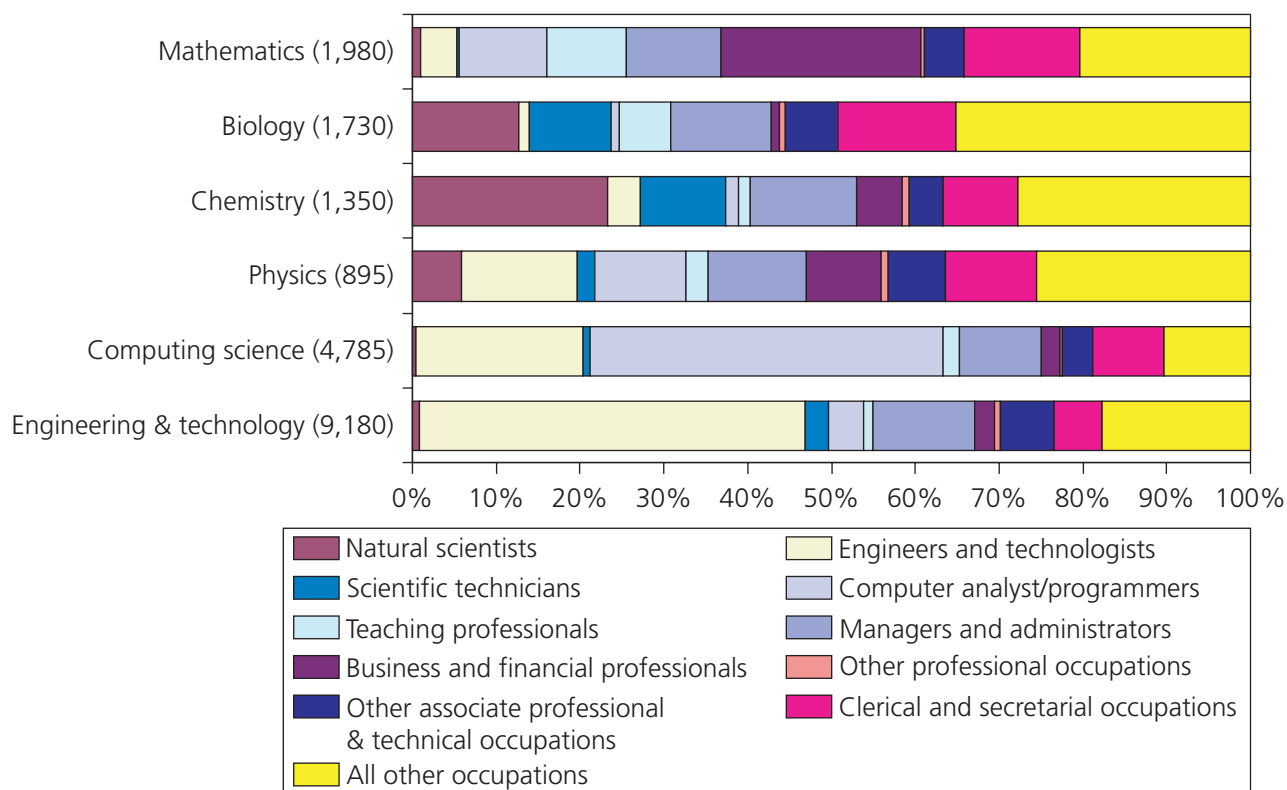
Figure 6.6. First destination of full-time UK- and other EU-domiciled first degree graduates by Standard Occupational Classification for selected STEM subjects, 2002/03 (HESA data).
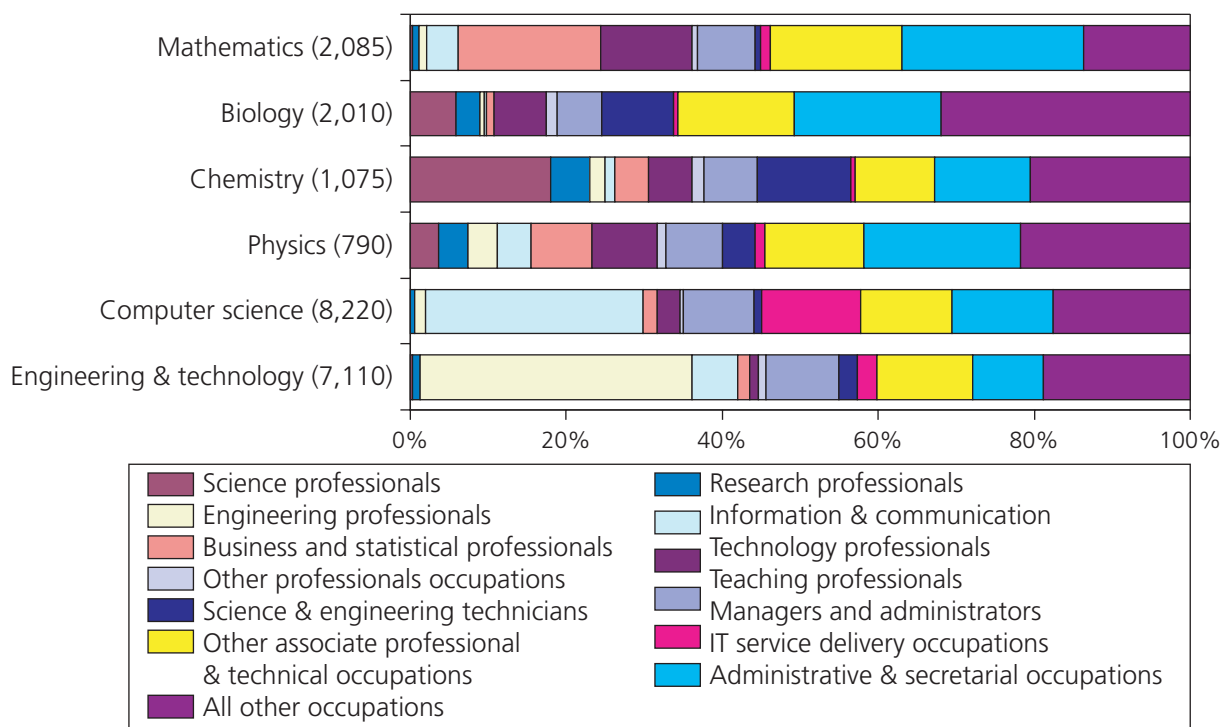
*Figure 6.7. Analysis of UK-domiciled first degree graduates entering further study only or further study and employ-
ment, 2003/04 (HESA 1997–2006c). The figures in brackets represent the number of graduates entering further study
and further study & employment.*
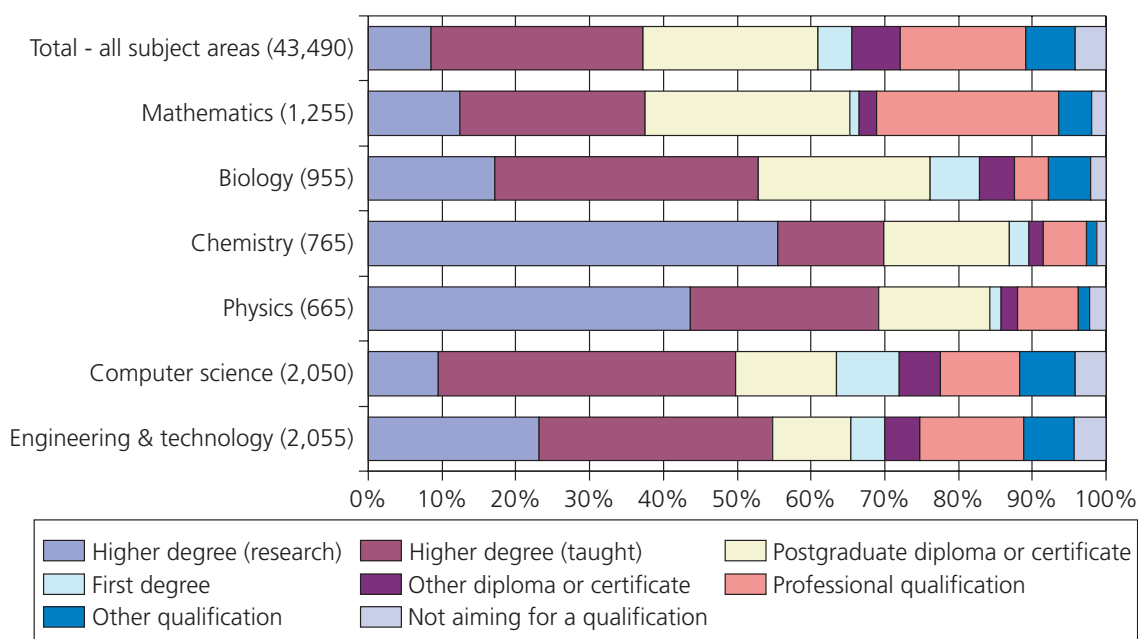
employed in graduate-level occupations six months
after graduation.

• A significant proportion of first degree graduates are
employed in administrative & secretarial occupations
six months after graduation. This classification would
be consistent with most of the temporary positions
that many graduates take-up in the period after their
degree.

6.3 Further Study

The first degree graduates who enter further study either
full- or part-time are a significant proportion of the
graduates in science and mathematics subjects.
Furthermore, many of these are likely to be planning to
pursue a career in their degree discipline or one that is
related to it, either through a PGCE, a specialised taught
masters or a research degree. Figure 6.1 indicates that in
biology, chemistry and physics the proportion of those
undertaking study as opposed to full-time employment
has fallen, although the numbers are still significant. In
mathematics the percentage of those undertaking further
study or a combination of work and study has increased.

Figure 6.7 provides a further analysis of UK-domiciled first
degree graduates whose destination is either further
study only or a combination of further study and
employment for 2003/04. Here, the 'postgraduate
diploma or certificate' category includes PGCEs and the

'professional qualification' category includes, for
example, accountancy qualifications.

Key points to note are:

• There are clearly major differences in the patterns of
further study within STEM subjects, with, for
example, higher degrees mainly by research (PhD,
DPhil, MPhil, MRes etc) accounting for over 55% of
chemistry and 44% of physics first degree graduates
who enter further study, but just 12% of
mathematics and under 10% of computer science
graduates who enter further study. It is also important
to note that the proportion of first degree students
entering further study varies between subjects, as
shown in Figure 6.1.

• Similarly, the proportion of first degree graduates
studying for a higher degree mainly by taught course
(MSc, MA etc) varies from 14% in chemistry to over
40% in computer science.

• The postgraduate diploma or certificate category,
which includes those on PGCE courses, represents
15% of physics, 17% of chemistry, 23% of biology
and 28% of maths first degree graduates in further
study. However, these are only a proportion of the
acceptances on PGCE courses, indicating that many
of the latter must be graduates from previous years,
either entering teaching after a 'year out', temporary
employment or as career changers.

- Studying for a professional qualification, for example accountancy, represents just 5% of biology, 6% of chemistry and 8% of physics graduates in further study, but nearly 25% of maths graduates.

- There are first degree graduates studying for a second first degree. This may imply that there are some graduates who are dissatisfied with their first degree discipline, or who decided they wish to start a professional career that requires a different first degree. For example, students pursuing the accelerated medicine degrees open to applicants with a related first degree (such as the ones offered at the universities of Newcastle or Warwick) are classified as first degree students again; this could explain the relatively high proportion of biology graduates undertaking a second first-degree.

7 Demand for STM graduates

This chapter discusses the demand for STM graduates. Section 7.1 explores the difficulties in any assessment of the quantitative demand for STM graduates in the future and details the Government's assessment of future demand for science, engineering and technology skills. It also considers the demand for science and mathematics school and college teachers and first degree graduates for postgraduate study. Section 7.2 discusses the findings of a literature review on the expansion of HE commissioned for this report, which considered evidence on the graduate premium.

7.1 Employer demand for STM graduates

7.1.1 How can we assess the quantitative demand for STM graduates?

An assessment of the demand for STM graduates has been an integral part of the work of the project and will be an element of the ongoing study, *Science HE 2015 and beyond*. At present, we emphasise the following points about assessing quantitative demand for STM graduates:

(a) Any attempt at estimating the total number of graduates with particular skills that will be required by the economy on the extended timescales relevant to education policy is fraught with obvious difficulties, not least because of the likely changes to the make up of the UK economy with the rise of economies elsewhere in the world. There is a danger that the migration of manufacturing jobs to emerging economies could lead to the migration of design and research capabilities. On the other hand, it is essential for the UK to create the conditions that will provide high value employment for its high density of population. The UK, along with other developed countries is seeking to develop an advanced knowledge-based economy, but it is not yet clear exactly what this will involve in the longer term.

(b) The requirements of the public service sector may appear easier to forecast, but even that can be difficult, because of possible changes of structure and methodologies into the future.

(c) The human resources requirements for particular future scenarios, such as achieving targets for UK gross expenditure on R&D (GERD) can be estimated using simple proportions: for example, the UK Government target in its ten year science and innovation framework (HMT 2004) for GERD to reach 2.5% of GDP by 2014 would require about 50,000 additional research staff and, because many of these posts will be in applied research, there will also be a requirement for many other staff with STM qualifications to exploit this activity. However, in

estimating the required level of output from HE, account must be taken of retirement demographics, the international market for highly qualified people, and the migration out of STM jobs at various stages of a career.

(d) The present HE system has significant flexibility and redundancy (as shown in Figure 3.1), which can accommodate sudden increases and decreases in demand; any changes to the HE system must retain this flexibility.

(e) There are at present shortages in particular areas, and for disciplines and sub-disciplines with small numbers of students. For example, a study by the Association of the British Pharmaceutical Industry (ABPI 2005) found that a shortage of pharmacology, physiology and pathology graduates was impacting on UK industry. Closer monitoring of student numbers is needed in these areas. In some areas increased supply could be achieved through conversion courses, possibly at MSc level.

Although it is difficult to estimate the overall numbers of researchers and other professional scientists technologists and mathematicians that will be required, and even more difficult to estimate the numbers in specific disciplines, we believe that the development of the UK as a major knowledge-based economy will require:

- an excellent and vibrant university research base, with a wide spread of subjects;

- a sustained supply of STM professionals, including school and college teachers, university faculty, researchers and technicians in the public and private sectors, with appropriate skills, knowledge and experience; and

- a good mix of discipline backgrounds, crucially including science and engineering, within the general graduate work-force.

Any review of employer demand for STM graduates must take account of quality as well as quantity issues, and questions surrounding the skills, knowledge and experience that it is desirable for STM graduates to develop through their studies are considered in chapter 8. There is much more scope for work on the qualitative factors, including ensuring that HE courses at all levels are satisfactory as an introduction to initial employment and as a start to lifelong learning, and that they equip their alumni with the flexibility to change directions as and when this is required. It is also essential that these courses are able to attract an adequate proportion of the most able and motivated students.

7.1.2 The Government's assessment of future demand for science, engineering and technology skills

One of the key aims of the Government's ten-year investment framework for science and innovation (HMT 2004) is to review annually the relative balance between the supply of and the demand for skills, and to recommend whether there is need for further action by Government or others. The second annual report of the framework (HMT 2006b) states that:

- the overall position of the UK in terms of its stock of STEM skills is a strong one: according to the OECD the UK compares favourably on the supply of STEM skills and there are signs that the UK's relative position has recently improved further. However, although numbers of entrants to HE have increased in some areas (for example, subjects allied to medicine), they have decreased in engineering and the physical sciences (especially chemistry);

- high earnings returns to subjects like mathematics, engineering, computing and the physical sciences suggest that there is high (and for engineering, increasing) demand for graduates with these skills. The Government expects that more students will pursue these subjects as they become more aware of the employment and earnings prospects that they offer;

- projections suggest an increasing demand for STEM skills over the next ten years. However, these projections are not broken down by individual subject and rely on several assumptions, in particular the continuation of historic growth in demand for skills. At the broadest level, it is believed that supply of STEM skills is likely to meet demand over the next decade. However, there may be problems with specific science subjects.

The document also notes that at present over half of STEM graduates do not enter employment in a STEM occupation straight away. The increasing graduate premium in engineering suggests that the market for these skills is adjusting to the reduced flow.

Two other recent documents have been published by Government departments, *Science, engineering and technology skills in the UK* (DTI 2006), and *The supply and demand for science, technology, engineering and mathematical skills in the UK economy* (DfES 2006b), which give further background information. Both of these documents point to the increasing number of graduates in the working population drawing on successive Labour Force Surveys of the qualifications of the 16- to 59/64- (female/male) year-old population. As indicated in section 3.2.2, this is the result of the increasing number of graduations per year since the 1960s, with these graduates replacing non-graduates retiring from the population. However, these figures have to be treated with care in any

policy work since some of those retiring from the labour force, although not graduates, may well have had other sub-degree HE qualifications, often obtained part time. Furthermore, there appear to be problems with these data in that the increases reported in some subject groupings in some years are significantly greater than the number of new graduates within those groupings.

A major outcome of the present study has been that taking broad subject groupings and high level comparisons with other countries can be misleading, and this is hinted at in the outcome of the Government studies listed above.

7.1.3 The demand for science and mathematics school/college teachers

As indicated elsewhere in this report, one key area of demand for STM graduates is in school/college teaching. The priority for increasing capacity in the school/college sector is to ensure science teachers with appropriate backgrounds are recruited, retained and given access and entitlement and necessary encouragement to gain professional development throughout their careers. A skilled, enthused and appropriately deployed teaching profession will be able to tackle some of the weak points in the education system: maintaining interest in science through the notoriously difficult transition from the end of primary school into secondary school; raising the profile of vocational science and engineering courses; and motivating students to continue with physics, chemistry and maths post-16.

There was a significant fall in the number of acceptances to PGCE courses in physics, chemistry and particularly mathematics after 1994, followed by an uplift starting in 1999 (Figure 7.1).

School teaching attracts a significant proportion of the graduates in some STEM subjects. Table 7.1 compares the 2004/05 graduation numbers in biology, chemistry, computer science, mathematics and physics with the acceptances to PGCE courses. However, care has to be taken in interpreting these figures as PGCE courses attract not just recent graduates, but also significant numbers who are seeking to qualify for a second career in teaching. Additionally, graduates in one subject may chose to train to teach a related subject – for example, significant numbers of physics and engineering graduates are accepted on mathematics PCGE courses. As Figure 7.1 shows, the worrying fall in the number of acceptances to mathematics PCGE courses up to 1998 has been reversed, at least partly due to the incentives offered by the Government to attract more mathematicians into school teaching, including attracting mathematics, physics and engineering graduates who were in employment in other sectors.

More generally, the Training and Development Agency for Schools (TDA) indicate that more than a third of people

Figure 7.1. Acceptances to PGCE courses in science and mathematics subjects, 1994–2004 (GTTR data).
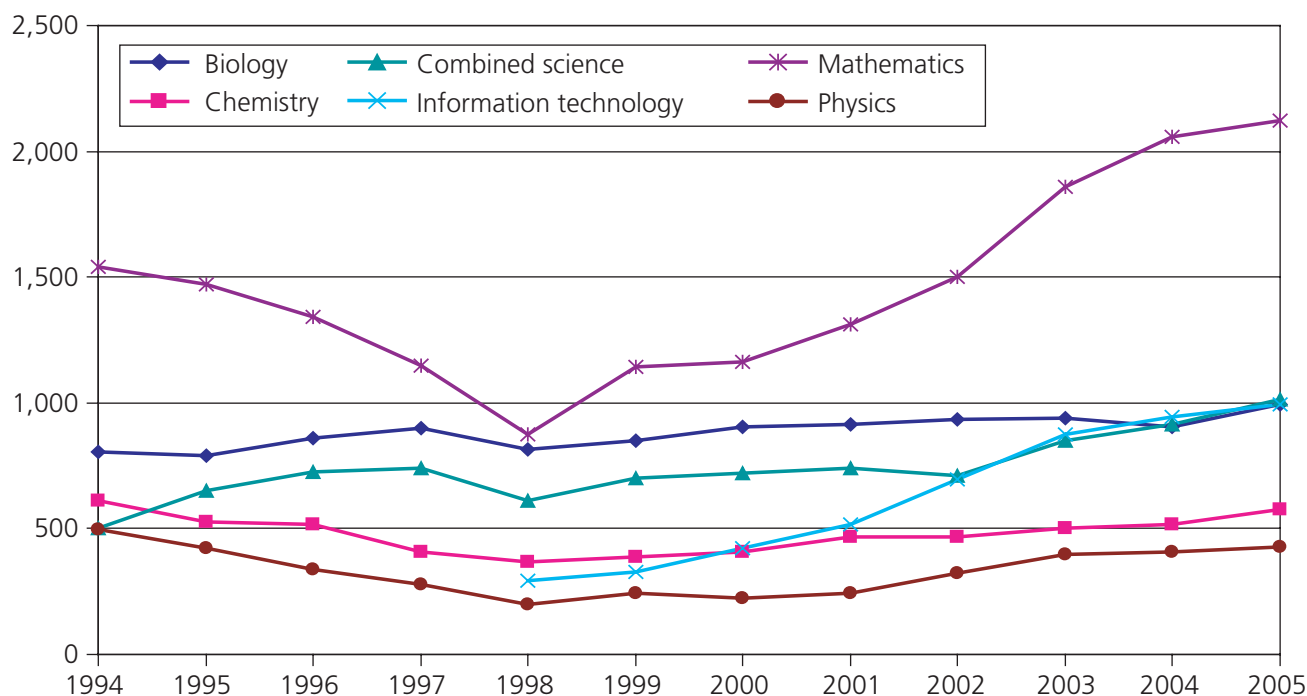
Table 7.1. Comparison of the number of graduates in selected science and mathematics subjects and the number of PGCE acceptances for those subjects in 2004/05.

Subject	2004/05 first degree graduates	2004/05 PGCE acceptance	Percentage of graduates
Biology, botany and zoology	5,270	905	17
Chemistry	2,715	515	19
Computer science	20,095	945	4.7
Mathematics	5,270	2,060	39
Physics	2,255	410	18

entering teacher training are over 30 years old, with many having worked in another field before entering the profession (TDA 2005). A survey of 570 newly qualified secondary teachers who worked in a different industry before becoming teachers was done on behalf of the TDA in November 2004. The research found that 24% of the newly qualified mathematics teachers in the sample had previously worked in either banking or accountancy, and 16% of the newly qualified science teachers surveyed had previously worked as scientists or pharmacists.

In the paper published at the time of the 2006 budget, *Science and innovation strategy 2004–14: Next steps* (HMT 2006a), the Government set out a commitment to step up recruitment, retraining and retention of physics, chemistry and mathematics specialist teachers, so that by

2014 25% of science teachers have a physics specialism; 31% of science teachers have a chemistry specialism; and the increase in the number of mathematics teachers enables 95% of mathematics lessons in schools to be delivered by a mathematics specialist (compared with 88% currently). With retirements among science teachers over the next ten years expected to be at least as high as the average number of retirements among all secondary school teachers (estimated to be between 33% and 40%), this aim is particularly ambitious and will require the Government to invest heavily in professional development and/or alternative sources of recruitment for subject specialists if the long-term shortfalls against its targets persist (Royal Society 2006).

7.1.4 The demand for first degree graduates for entry to postgraduate research degrees

The demand for STM doctoral level graduates by academia, and public sector research and business R&D activities, remains high in chemistry and physics; entry to research degrees is the first destination of a significant proportion of graduates in those subjects (Figure 6.7). Although the proportion is lower in biology and mathematics, postgraduate study still represents an important career path in these disciplines.

7.2 Literature review on the expansion of HE: pay and the graduate premium

If the number of jobs requiring graduate skills has not kept pace with the supply of graduates entering the

employment market, this may be reflected in several labour market indicators, such as an increase in the proportion of graduates working in non-graduate jobs or a decline in the wage premium for graduate workers. To explore these questions further, we commissioned a short literature survey (J Durning 2005, personal communication) of serious studies of the effect of the major expansion in participation in HE, including some cohort studies. The main findings were:

- Recent empirical evidence from large-scale surveys on the first three to four years of graduate careers points to the rapid changes in the sorts of job that graduates do in the first year after graduation and casts doubt on the value of HESA first destinations statistics.

- A significant minority of the graduate population is on paper apparently over-educated for their current job, but there is little or no evidence that the proportion has increased as HE has expanded.

- There has been a levelling-off of the graduate premium, but graduates continue to be paid more than those with lower qualifications even if they are working in jobs for which they are overqualified.

- Career-related work experience is very important.

Many of these studies were not specific to STM graduates: section 7.2.1 considers general reports on the graduate premium and section 7.2.2 considers those studies that are specific to science or mathematics graduates.

7.2.1 The graduate premium

Some information on the demand for graduates can be obtained from starting salaries and graduate premiums, compared with those qualified to enter HE but who for some reason do not do so. The maintenance of the graduate premium has been a major plank in the Government's arguments for the expansion of HE, and for a greater contribution from the student towards the cost of their studies. However, the situation is complex as those who do not enter HE may include an increasing proportion of those with less career ambition, or with responsibilities for family care, either of which may in any event depress future earnings.

The graduate premium has been studied by several academic groups. Walker and Zhu (Walker & Zhu 2003) and Elias and Purcell (Elias & Purcell 2003) have provided some evidence that the premium has been maintained over the expansion of HE. However, a further exploration of the data from two cohorts of graduates in 1980 (Dolton *et al.* 1990; Dolton & Makepeace 1992) and 1995 (Elias & Purcell 2004) has indicated that there is some evidence of a downturn in the relative salaries of recent graduates, a finding also reported by Chevalier and colleagues (Chevalier *et al.* 2004). O'Leary and Sloane

(O'Leary & Sloane 2005) have attempted to evaluate the change in premium over the period 1993 to 2003 using the Labour Force Survey over that period, and have provided some more quantitative evidence for a downturn in the premium, especially for women. The downturn is more pronounced in the lower reaches of the skills/earnings distribution and more concentrated for arts degrees than for other subjects. O'Leary and Sloane conclude that although demand for graduate skill has also been increasing over the same period, it does not appear to have compensated for supply changes.

In their most recent publication, Purcell *et al.* (DfES 2005) return to the issue of graduate earnings considering a cohort who graduated in 1999. They note a wide range of earnings, dependent on the subject studied, the employment sector, and a range of related variables. A comparison of this distribution with that of 1995 graduates shows no indication that the range is widening. They find that although there is little difference in pay between different categories of graduate job (for example, traditional graduate jobs and new graduate jobs), in line with the findings of other studies on over-education, there is a significant difference between graduate and non graduate jobs: those in non graduate jobs earned on average 13–19% less than those in the graduate SOC occupation groups. Those who said that a degree was required for their job earned on average 6% more than those who did not, even if the job was classified as non-graduate by SOC. The class of degree was also significant: on average, a first or 2.1 added 11% to earnings.

Overall, earnings and salary growth in the first few years are highly significant: 'it appears that employers continue to be prepared to pay a premium to employ graduates, even in jobs that also employ non- graduates' (DfES 2005). But the rate of increase of earnings of the 1999 cohort has not kept pace with the rate of increase more generally in the economy: graduate earning rose by 22% between 1998/99 and 2003/4, for graduates at a similar stage in their career, compared with 25% over the same period in the whole economy. This is flagged as perhaps the most significant finding in the DfES report. The authors suggest that it may be particular to the cohort, or may be a first indication that the premium is beginning to reflect a decline in the demand for graduates.

Purcell *et al.* point out that, within the diverse career paths followed by the wider graduate population, there is still an elite – a top 10% equivalent to those who participated in higher education before the expansion of the 1980s and 1990s – who will attend the 'best' universities, get the best jobs, and many of whom receive the highest return on their investment in education.

7.2.2 The graduate premium for science subjects

A recent study by PricewaterhouseCoopers (PwC) for the Royal Society of Chemistry and Institute of Physics

Table 7.2. Rate of return to the individual and to the taxpayer from a first degree by discipline, where the return to the degree holder is compared with that of those in possession of two or more A-levels as their highest qualification. (PricewaterhouseCoopers LLP 2005).

First degree subject	Additional discounted net lifetime earnings	Rate of return to the individual	Rate of return to the taxpayer
Law	£246,367	17.2%	19.3%
Management	£152,947	16.9%	19.7%
Engineering	£219,971	15.5%	13.1%
Chemistry	£186,307	15.0%	12.1%
Physics	£188,249	14.9%	13.0%
European Languages	£163,466	14.0%	16.6%
Social Sciences (excluding law and psychology)	£154,135	13.5%	16.2%
Medicine (excluding dentistry)	£346,156	11.6%	7.8%
Biological Sciences	£109,845	10.2%	9.5%
Psychology	£100,479	10.1%	10.9%
Linguistics/English/Celtic studies	£92,797	9.7%	12.1%
History	£89,630	8.8%	10.4%
All degrees (currently)	**£128,771**	**12.1%**	**12.1%**
All degrees (after student finance reforms being introduced in 2006/07)	**£125,315**	**13.2%**	**11.0%**

(PricewaterhouseCoopers LLP 2004) considered the economic costs and benefits (to the individual and the state) associated with education to first degree standard in chemical sciences and in physics. These were compared with those with two or more A-levels as 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;

- the figure of 30% compares with between 13% and 16% for graduates in subjects including psychology, biological sciences, linguistics and history.

The graduate premiums from the PwC report, including the returns to the student and the public purse through additional taxation, are shown in Table 7.2. Annex 7 gives some further information on the graduate premium, including the average starting salaries for graduates from a wider range of first degree subjects.

The data for this study came from pooled information from the Quarterly Labour Force Surveys between 2000 and 2004. This data source has detailed information on qualifications, earnings and employment status at an individual level. The study also modelled the impact of the student finance reforms (set out in the 2004 HE Bill) on rates of return. The results indicate that the rate of return to the individual increases following the reforms, but this assumes no change to HE participation rates or the distribution of students between subjects (ie students are not discouraged from applying nor opt for 'cheaper' subjects as a result of differential top-up fees).

The recent study by O'Leary and Sloane (O'Leary & Sloane 2005) also looked at discipline related graduate premiums. They concluded that the rapid expansion of the HE system in the UK has not led to a wholesale decline in the value of degrees in the labour market: for example the value of maths, computing, engineering and technology degrees have increased on average.

8   STM first degrees: skills, knowledge and experience

This chapter considers the skills, knowledge and experience that it is desirable for STM graduates to have developed through their undergraduate study. Section 8.1 explores what a first degree should prepare students for and section 8.2 discusses the skills, knowledge and experience that it is desirable for STM graduates to have.

8.1   What should a first degree prepare students for?

Graduates from STM first degrees enter a wide range of occupations, some of which will directly use the subject knowledge gained through their degrees and some of which will only draw on the wider skills that their HE experience has developed. First degrees are also a precursor to further study, either in a directly related subject or in a new area, and to PGCE courses for those who plan to enter teaching. Increasingly, as employment patterns change and many people have at least one career change in their working lives, first degrees are the start of a lifetime of learning and development, which may draw on different aspects of a graduate's HE experience at different stages.

Although this report is mainly concerned with STM first degrees as a preparation for a professional STM career, it is highly desirable that STM graduates should enter other areas of the economy. The wider societal benefits of having people with a science or maths background in areas such as journalism, law, politics, policy-making, local government and, more generally, as citizens, are increasingly well understood. Scientific and mathematical literacy among the population are important to the well-being of democracy in a world in which science and technology have a bearing upon so many aspects of life.

Defining exactly what constitutes a professional STM career is difficult. For this report, a wide view has been adopted in which a professional STM career is defined as one which makes significant use of a proportion of the core skills and knowledge developed in an STM degree (or related further study), combined with a requirement for continuing to develop knowledge of new developments in the field as relevant to the chosen career. This definition includes the following career choices:

- school and college teaching;

- academic research/teaching;

- applied research and development in the public services and business;

- professionals in STM-related services: eg medical physics, analysis and monitoring activities in public services or business, consultancy, actuaries;

- STM-related management – management of STM based activities in public services and business;

- STM-related journalism, policy work and science communication activities;

- use of mathematical and other STM techniques such as analysis and modelling in other areas such as finance or computing.

Some of these career paths will require further study such as a PGCE or a higher degree, and a range of more generic skills such as communication skills, team working and a 'self-starting' attitude.

A key tension we have identified is that between the needs of those who will go on to pursue professional STM careers and those who will enter other areas of employment – the opposition between first degrees as specialist training and first degrees as generalist education. First degrees in STM can serve both of these aims, especially since many undergraduates are still uncertain about their future career plans, and many graduates who successfully pursue other careers benefit from the high level of analytical, mathematical and modelling skills that STM first degrees develop. Furthermore, this is the basis of the flexibility that is needed in matching degrees to final career options discussed in chapter 3, which needs to be preserved.

Nevertheless, there may be some undergraduates for whom other options would be welcome. For example, some might find special 'practical-light' options in the third year of value, where other modules could be taken in place of a project or some of the practical work. Some universities offer general science courses, and the post-1992 universities in particular have pioneered some imaginative mixed discipline degrees. Another approach would be the development of courses that develop an understanding of the wider philosophical, historical and economic context of science, such as the 'science greats' course pioneered at the University of Manchester during the 1960s (Jevons 1967).

Such changes would, however, have impacts beyond first degree courses. There would be a need to develop routes to postgraduate study, perhaps through specialist masters courses, for those who after taking a more general science course wished to pursue scientific research or a more specialised STM career. There would also be associated implications for the total length of time that such a student would take to reach doctorate level. This is one of the motivations for the second phase of this project, which will look more comprehensively across the HE system, from first degree to PhD.

8.2 What skills, knowledge and experience is it desirable for STM graduates to have?

8.2.1 Skills and knowledge developed by STM first degrees

Attention to 'graduate attributes' has increased as an expanding university sector seeks to demonstrate to the wider world that its graduates possess, in addition to disciplinary knowledge and associated skills, the skills, knowledge and attitudes that are valued by potential employers. Employers have also started to specify the generic skills that they are seeking among those they employ.

The Quality Assurance Agency (QAA) subject benchmark statements (a set of statements setting out expectations about standards of degrees in a range of subject areas and defining what can be expected of a graduate in terms of the techniques and skills needed to develop understanding in the subject) and the Council for Industry and HE *Student employability profiles* (CIHE 2005) outline the skills that are expected to be developed by various subjects at undergraduate level. Similarly, the Biosciences Federation report *Enthusing the next generation* (Biosciences Federation 2005) explores the skills and knowledge that should be developed during biosciences education, from primary school to university. Drawing on these and our own views a suggested list of the 'skills' (in the widest sense) that studying science or maths at undergraduate level should develop include:

- coherent, in-depth and quantitative knowledge of a discipline, allied with fundamental practical experimental competences;

- oral and written skills;

- knowledge of how scientific knowledge is obtained, validated and subject to change;

- ability to think scientifically, to analyse situations logically, identify options and reach decisions;

- commitment to independent, lifelong learning;

- ability to work cooperatively and productively as part of team;

- competence in using information and communication technology (ICT) to acquire, organise and present information;

- ability to think mathematically, to process, present and quantitatively analyse numerical and other scientific data;

- a willingness to seek, identify and implement improved solutions and, where appropriate, to suspend judgement.

The extent to which STM graduates actually develop these skills at present is unclear. The diversity of STM provision in the UK HE system naturally leads to a range of first degree courses, some of which will emphasis different sub-sets of these skills. Students intending to study science at university need to be more aware of the skills and attributes that can stem from doing so. This would be helped if science departments were more explicit about the skills and attributes that come from studying science at undergraduate level, and developed courses to promote these skills. The specification of these skills needs to take account of the needs of the major employers of their science graduates.

8.2.2 First degrees as preparation for higher degrees, taught masters and PhDs

By international standards the UK is very unusual in progressing first degree chemistry and physics graduates straight through to PhD programmes without any intervening masters-level studies (above MSci level). This creates a very efficient system in terms of the age at which students can achieve a PhD, but has the downside that (in England and Wales at least) the individuals concerned have been narrowly educated since the age of 16 when they made their subject choices at A-level.

Until now French and German PhDs have been much older than their UK counterparts when they completed their doctorates and employers have indicated that they value the benefits of the broader education and training that they have undertaken. However, in view of changes to the HE systems in these countries in response to the Bologna process, the differences between UK and other European PhDs may reduce.

8.2.3 First degrees as a preparation for school teaching

Potentially, secondary school teachers need to be equipped to teach the full range of pupils from year 7 to A-level students. This causes conflict between the general science orientation of 11–16 work up to and including GCSE, and work for A-levels. It is essential that there is diversity in the degree disciplines of the science teachers within each school, and that no one discipline unduly dominates. At present, overall biological science graduates or ITT graduates with a biology specialism account for some 44% of science teachers, with 19% with a physics specialism and 25% with a chemistry specialism (DfES 2006a). Since in some schools there is a more balanced staffing, in others the imbalance will be worse than this, and over a quarter of 11–16 schools do not have any teachers from a physics background and 12.5% of such schools have no chemists. It is not helpful that generally available statistics, in particular those associated with ITT and PGCE student numbers, are now largely in terms of 'science' teachers, rather than the individual disciplines. Nevertheless we are encouraged by the Government's

targets set out in the *Next steps* document (HMT 2006a) to work towards 25% of science teachers having a physics specialism and 31% having a chemistry specialism, and furthermore that 95% of mathematics lessons in schools should be delivered by a mathematics specialist (see chapter 7.1.3).

8.2.4 First degrees as a preparation for employment as an STM professional

The main recruiters of STM graduates have traditionally looked for technical knowledge and intellectual capability in those that they employ. There appears to have been an increased emphasis in recent decades on combining subject expertise with good interpersonal skills, practical employment experience and commercial understanding. The respective roles of the HE system, employers and the undergraduates themselves in developing these attributes have been less clearly articulated.

Core subject knowledge and skills

A recent study carried out for the Royal Academy of Engineering by Henley Management College through a series of interviews with large companies, SMEs, spin-outs and recent engineering graduates (RAEng 2006) found that the top priorities in terms of the skills desired by industry were practical application, theoretical understanding and creativity and innovation. Broader technological understanding was also seen as important, but not at the expense of understanding the fundamentals. The key business skills identified as important were primarily commercial awareness – an understanding of the businesses work and the importance of the customer – combined with a basic understanding of project management.

The study found that the requirements of large companies and SMEs were very similar. A key difference, however, was that SMEs prefer graduates with some experience of the commercial world before recruitment, whereas large companies with their own graduate training schemes recruit directly from university. The reduction in the number of large STM-based firms has implications for company based training schemes, and the role of universities for continuing professional development.

A similar industry survey conducted by the ABPI (ABPI 2005) identified the following core graduate skills for the pharmaceutical and biopharmaceutical industries: mathematical ability; practical experience (laboratory work); *in vivo* skills; communication skills; computational analysis skills; and chemistry skills. Although some of these are specific to the pharmaceutical industry, others are clearly applicable to a range of STM employment. The report also identifies concerns about modular degrees allowing students to avoid 'essential but difficult' subjects by selecting 'easier' modules.

Surveys of employers of chemistry graduates and employers of engineers, scientists and IT specialists, which were carried out in the late 1990s for, respectively, the Royal Society of Chemistry and the Council for Industry and Higher Education (Mason 1998) and the DfES (DfES 1999), found that the main skill deficiencies in STM graduates emphasised by employers were lack of practical/work experience, lack of commercial understanding and gaps in inter-personal and communication skills. Only a small minority expressed concerns about gaps in technical knowledge among people they had interviewed. However, there was a sense that graduates with technical shortcomings were sifted out before the interview stage by only offering interviews to graduates from university departments with 'good' reputations. The main problems set in therefore when technically competent graduates from highly regarded university departments were found to lack other desired qualities.

The departments and agencies of the UK Government are also major employers of science graduates. The 'professional skills for Government' initiative provides a skills framework for progression within the civil service as a scientist (DTI 2005). Although the first gateway specified is significantly above the standard graduate entry point, it is not difficult to infer from the framework which skills would be highly prized in a graduate scientist. In brief, these include both academic qualifications, and the ability to apply this knowledge in combination with other skills and experience. Much is made of the need to communicate work effectively, via presentations and scholarly articles, and the need to network effectively.

With the increasing amount of student-led choices of subject modules and coursework, which provide differing balances of knowledge and skills, it is clearly vital for students to have access to up to date and reliable careers advice when making such choices. There are also courses aimed at particular careers – for example, some forensic science and medicinal chemistry courses – which are not considered by most employers as having sufficient core chemistry content for those wishing to follow a forensic science or pharmaceutical career. This illustrates the need to involve employers in the design of such courses.

The role of work experience

Graduates who have gained work experience during their studies are highly valued by many employers, but in many subjects it is difficult to find employers willing to offer such work placements. For many smaller companies it can be particularly difficult to offer such experience. The pressure on graduates to arrive in employment with prior practical experience partly reflects the intensification of competitive pressures facing employers in many sectors combined with the effects of 'delayering' in many organisations, resulting in fewer people being available to supervise inexperienced graduate recruits.

Feedback mechanisms

Relationships between university departments and employers tend to involve primarily large firms, and be confined to only a few such relationships per department. They are often focused on research or knowledge transfer, rather than on curriculum development. In addition, most SMEs lack the resources to engage in such relationships, although there are notably exceptions in highly science-dependent sectors. There is also an important role for university careers services to play in maintaining links between universities and employers.

It is vital that as the needs of UK employers develop and change, the requirements of STM employers are articulated to the HE sector effectively. In particular, HE institutions developing new courses, especially those that appeal to students hoping to enter particular careers or employment sectors, should seek employer involvement in the course design and structure.

9   Discussion

9.1 Introduction

This final chapter draws together and comments further on the issues set out in chapters 2–8, and highlights areas that warrant further study either within the Society's *Science HE 2015 and beyond* study or otherwise.

A recurring theme throughout this report is the need to look behind headline figures, particularly where these are related to major groupings of subjects. For example, while the early stage of secondary science should be an integrated science curriculum, major problems arise if the teachers are predominantly graduates in one of the main disciplines: currently science teachers are largely graduates in biological sciences. Similarly, hidden within the claims of buoyant number of graduates in biological sciences, there are problems within biology that are masked by the major increases in psychology and sports science courses.

Another general issue highlighted in the report is that temporal and international comparisons also have to be treated with care. For year-to-year comparisons it is essential to eliminate as far as possible discontinuities in definitions. This is particularly true in the case of long term datasets for HE where information from various sectors was collected by different bodies but, as shown by the problems highlighted in chapters 5 and 6, this is also a problem with more recent HESA data. Comparisons between countries bring in a host of other problems, which need to be explored carefully if these form an important plank in the development of any major policy. For example, international comparisons of participation rates must take account of the different higher educational arrangements in the comparator countries and also take account of drop out rates.

9.2 Global, European and domestic developments with implications for the future development of UK HE

The future development of UK HE has to be considered in the light of accelerating developments within the major emerging economies in the world, which have severe implications for the economies of all developed countries. The latter are increasingly concerned to ensure that their HE systems remain internationally competitive, in order to ensure that their workforces are capable of maintaining 'advanced knowledge based economies' in the face of the emerging intense international competition. At this stage it is not totally clear what an advanced knowledge-based economy will entail, but a high-quality graduate workforce is clearly a prerequisite.

Within the EU, the Commission has been charged with exploring how to increase the performance of European universities and also with taking forward the Bologna process to harmonise degrees across Europe. It is vital for the UK to be involved and influence these developments. The European developments, together with those within the UK set out in section 3.1.1, pose a significant challenge to UK universities.

The investment in HE by the UK is comparable to that of the larger European countries, but is much less than in, for example, the USA and Sweden. In addition to the large private sector contribution, the US public investment in HE as a percentage of GDP is higher than the total UK investment in HE. In terms of drop out-rates and length of courses the UK appears to be more efficient than other European states and the USA, but it is unlikely that this will compensate for the imbalance of investment compared with the USA.

Both of the established comprehensive international university league tables of elite universities place the UK in second place to the USA (see section 2.1.3), but the position could easily change over the next decade if the UK system does not strive to remain competitive with world leaders in HE.

UK universities attract foreign staff and students as shown in Figures 2.2 and 2.3. In the case of masters courses, foreign students make up over half of the students. Some 40% of research-only staff are foreign, and although in the case of faculty the percentage is much lower, this masks concerns expressed by some leading institutions that in some disciplines they have been unable to attract competitive UK candidates for such positions.

9.3 The overall UK HE system

The current UK undergraduate HE system, shown diagrammatically in Figure 3.1, potentially provides significant choice to students over their future careers, and an analysis of the first destinations data (chapter 6) confirms the wide range of careers open to STM graduates. Overall there is also flexibility over the supply of graduates to employers, which is essential in view of their difficulties in providing forecasts of their quantified requirements for graduates even a year ahead, let alone over any timescale that could allow changes in the numbers of students choosing particular subjects. It is important not to lose this degree of flexibility both for graduates and employers by more carefully matching student numbers to directly relevant careers.

In examining the published figures for participation in HE and the target to move towards 50%, it is important to recognise that part of the increase is due to moving towards a more appropriate but wider definition, with an expansion of the age range from 18–19 to 18–30 years, and the inclusion of part-time students. In terms of student numbers, the main increase recently has been in those undertaking part-time other undergraduate rather than first degree courses.

Although there has been an increase in academic staff across the system over the five years between 1998/99 and 2002/03, these headline figures hide the significant decreases in permanent academic staff in chemistry, physics, mathematics and engineering.

The importance of income for teaching as a percentage of total university income varies widely across the sector, with the average of the top universities in terms of total income receiving under 20% of their income for teaching, whereas the post-1992 universities average over 65% of their income for teaching. As far as teaching income is concerned, Funding Council grants now represent a decreasing share of the total, with significant rises in income from non-EU overseas students. With UK universities receiving a decreasing share of the overall foreign student market (OECD 2005) as competition increases, this latter source may be at risk.

The unit teaching income is very difficult to calculate, except in the most general terms, where there was a major decrease up to 2000, with stabilisation since then. More disaggregated data at, for example, full-time equivalent first degree students would be helpful for policy development as would disaggregation to major disciplines. Similarly, until the new TRAC costing arrangements are fully in place for teaching in early 2008, there is insufficient information on the costs of teaching, and hence the adequacy of the resources available for this activity. However, laboratory-based courses, particularly those with significant practical projects in the final year, are expensive, and a factor in the recent closure, or potential closures of science departments.

9.4 The post-16/university interface

The supply of first year first degree students in STM subjects is largely from the pool of A-level, Scottish Highers and Advanced Highers candidates. Chapter 4 explored both the numerical supply of students taking relevant A-level subjects, and the qualitative issue of the match between output from current A-level courses and the expectation of prior skills and knowledge by the universities, particularly in mathematics.

9.4.1 The pool of qualified school leavers

The number of A-level entries in maths, physics and chemistry has declined since 1991 (Figure 4.1), with a

slight increase in biology. The situation has been similar with Scottish qualifications (Figure A3.1, Annex 3). There has also been a significant decline in those taking traditional combinations of three A-levels (Figure 4.2). This means that those entering first degree courses are likely to bring knowledge of a wider range of different subjects than previously, but less background knowledge of cognate disciplines can be assumed. Furthermore, within the A-level subject or subjects most relevant to the course, changes to the curriculum may reduce the prior knowledge that can be assumed. This appears to be a particular problem with mathematics, and is discussed further below.

In section 4.2 the following limiting quantitative factors were identified:

(a) in both chemistry and biology, the expansion in medical courses and the fact that these demand top A-level grades (and their Scottish equivalents) has resulted in these courses taking a high proportion of the A-grade A-level and Highers qualified students in these subjects, with adverse implications for recruitment into chemistry and biology first degree courses both in terms of quality and quantity;

(b) the number taking A-level mathematics is a limiting factor for any increase in the physical sciences and engineering, and A-level biology may also be a limiting factor in the biological sciences, particularly with the rise of psychology A-level;

(c) the number taking physics A-level may be a limiting factor in the numbers going onto physics and engineering courses.

These observations put the decline in A-level entries between 1992 and 2005 of 9% in chemistry, 19% in mathematics and 32% in physics into particular focus. The recent targets set by the Government to increase the number of entries by 2014 by 12% in chemistry, 21% in mathematics and 45% in physics (HMT 2006a) are welcome, and it is essential to monitor progress towards these. However, these increases should include at least the current proportion of highly motivated and able school pupils.

9.4.2 The key position of mathematics in the physical sciences and engineering

A good grasp of A-level mathematics is a prerequisite for physical science and engineering courses and, for some courses, A-level further mathematics is desirable. Although the biological sciences are often considered 'less mathematical', quantitative methods and statistics are important components of these courses.

On the other hand, the way that mathematics is required in engineering and arguably also in the physical sciences first degree courses has changed, with a greater

emphasis on the way that mathematics helps an understanding of physical and engineering processes, rather than in undertaking complex calculations, which are now undertaken using computer programmes. However, it is still essential for engineers to understand the logic behind these calculations (Ove Arup 2003).

As discussed in section 4.3.3, there are two issues that have been raised over current A-levels as a preparation for the mathematics knowledge and skills required within the physical sciences and engineering first degree courses:

- a major concern over the fluency in basic mathematical skills such as basic algebra and the properties of basic logarithmic, exponential and trigonometric functions; and

- a change in more advanced mathematics topics covered by A-level students.

Of these, fluency in basic mathematical concepts is of fundamental importance and requires urgent investigation because, even if treated with special courses in the first year in HE, it severely reduces the confidence and motivation of students over the theoretical parts of the undergraduate physical science and engineering curricula. Reports that even those with a grade A or B in maths A-level can have severe fluency problems would appear to indicate a problem that requires further investigation. We have heard evidence that UK students in some cases are less well prepared mathematically than their foreign peers.

On the coverage of specific advanced mathematical topics, there have always been differences in what is covered in particular A-level syllabuses. Furthermore, several proposals for a broader 16–19 year curriculum over the past 20 or so years have, in part, faltered on the problems that such broadening might cause in the HE sector. Any move towards a baccalaureate-type exam is likely to reduce the specialist knowledge that can be expected in new first year students, not just in mathematics, but other sciences as well. There is little evidence that the innate ability of students arriving with good A-level grades is lower than in the past, and the HE system will therefore have to adapt to the changes in topics or level of topics in the A-level syllabuses, rather than expecting A-levels courses to revert to earlier syllabuses. Nevertheless, in parallel with this, the HE community should articulate the skills, knowledge and experience that are perceived to be desirable in new undergraduates and to be involved, alongside other stakeholders, in shaping the future development of 14–19 education.

9.5 The provision of science and mathematics first degree courses

Chapter 5 provides an overview of the first degree courses designed to train professional scientists and the students on these courses. The time available within a three- or four-year full-time first degree course is such that professional scientists, technologists and engineers generally need to have followed a single subject first degree course in the relevant discipline. Multidisciplinary activity in both the public and private sectors is largely taken forward by teams of such specialists. There will, of course, be exceptions to this, and those following other routes may well be able to change direction through suitable educational and training opportunities, such as a relevant masters course.

In the sciences, most biology, chemistry, physics and mathematical graduates are from pre-1992 universities with departments with a significant research programme. In both physics and chemistry, in particular, there has been a major cull of departments where the research was rated 3b or lower in the 1996 RAE, and more recently of some higher-rated departments. Nevertheless there remains in the post-1992 sector, accredited and recognised courses, often in institutions where there is a relevant local industry. The post-1992 universities provide the bulk of the more specialist courses, such as those in analytical chemistry.

Trends in the number of graduates cannot be obtained by using successive volumes of annually published HESA data, because of changes in the way that joint honours degrees were allocated to subjects, and in some cases changes to subject definitions. A special run on the HESA database has shown that the claimed increase in mathematics graduates was not real, and that the number of mathematics graduates, along with those in physics and biology, were generally stable over the period, but with a major decrease in the number of chemistry graduates (Figure 5.5). Figure 5.6 shows the major expansion of sports science and psychology graduations within the biological sciences.

The high level of scholarship required for first degree STM courses needs to include a significant research presence or interaction with the problems of local businesses within the department concerned. This requires significant resources, not least of faculty time, and it is unlikely that fee income plus current Funding Council teaching grant has been sufficient to cover this for STM subjects. The new fee arrangements may well increase overall university income, but could well put further pressure on laboratory-based subjects.

The post-1992 universities have been successful in expanding and creating new science and technology based courses in some selected disciplines (eg computer science and psychology) and by bringing together various disciplines, sometimes including elements from the social sciences, arts and humanities. In many of these the number of graduates is very much higher than could be accommodated by immediately relevant employment and it is important that course providers make this clear. Nevertheless, like the traditional single subject sciences

and engineering courses, these courses provide a worthwhile general HE experience that is valued more generally by employers.

A significant proportion of students on first degree science and engineering courses do not continue with the discipline either because they do not find a suitable STEM career option or because they are positively attracted in another career direction. This is healthy as it provides flexibility to the graduate over career choice, and also scope to employers for filling vacant STEM posts, by making them more attractive.

There is some evidence from studies of graduate salaries that the more traditional subjects have a higher premium, but it is not clear that these have been corrected for other variables such as A-level score and in particular the premium for those with A-level mathematics (Dolton 2002, CLS 2006). Furthermore there are claims that the direct vocational value of some courses, such as some of the forensic science courses, have been over-sold to prospective students, with employers requiring much more in-depth knowledge of some of the component disciplines such as chemistry and law (SEMTA 2004).

Both single discipline and more general first degree courses are clearly required, but it is essential that the output from the specialist courses is sufficient for the needs of the overall economy. It is therefore important to analyse student numbers to this level of disaggregation, and not to rely on more generic groupings such as 'biological sciences' or 'physical sciences'.

9.5.1 The introduction of four-year integrated masters

The combination of the need for first year STM courses to interface better with the output from schools, the incremental nature of the subject, advances within the disciplines, and the fact that students on such subjects are expected by employers and the relevant learned society/engineering institution to graduate with a broad background in the discipline, has meant that a three year bachelors course has become insufficient for some of those who wish to continue as professional scientists and engineers. This has led to the introduction of 4-year integrated masters courses in engineering, mathematics and the physical sciences. There are claims that a sizeable proportion of the extra time is required because of changes to the content of A-level syllabuses. These four year courses are uncommon in the biological sciences.

Integrated masters at present account for about 30% of the chemistry, physics and engineering first degree graduates, but only 10% of the mathematics graduates. In the case of engineers those who aspire to Chartered Engineering status require this masters qualification or a

free standing masters. An integrated masters is not always required at present as an entry to a physical science PhD.

It has been questioned whether there is a sound pedagogic basis to the establishment of MChem/Phys/Eng, etc integrated masters courses, or whether they are too driven by financial considerations such as the different public funding arrangements for students at undergraduate and postgraduate levels, and the expectation that the normal route to a PhD in STM subjects is straight from a first degree. It is important to explore the growing differences between the biological and physical sciences in this area. The development of the MEng undergraduate course has effectively downgraded the status of the BEng degree, in that this is no longer a qualification that leads directly to CEng status after further professional experience. A similar impact could be seen in other subjects where integrated masters courses have been introduced.

Clearly there is a difference between these integrated masters courses and the specialist usually one year masters courses also offered by the universities. This, coupled with the potential downgrading of the BSc courses when integrated masters are also offered, is confusing to students and to employers.

9.5.2 Modularisation of courses

We are concerned that there is a danger that the trend towards modular first degree courses could lead to students being given insufficient opportunity to bring together concepts from various topics. The Quality Assurance Agency (QAA) is aware of the problem and is unlikely to accept as an adequate preparation for a degree a set of totally independent modules. Nevertheless, we believe that there should be work within at least the final year that requires students to draw on knowledge and skills acquired throughout the course.

9.5.3 Quality of courses and the impact of QAA and Accreditation

It is imperative to ensure that UK degrees are maintained at the highest international standards. There is a range of safeguards and gatekeepers controlling the quality of courses including the internal governance arrangements for the institution, external examiners, the introduction of professional qualifications for university teachers, the QAA oversight and for certain individual courses accreditation by the appropriate learned society or professional institution as fulfilling the formal educational requirements for particular professional status. The last factor has been particularly developed within engineering.

It would appear that within physical science and mathematics, accreditation and Chartered status are

regarded more highly by employers than by academia, and is largely unknown by prospective science and mathematics students. In the biosciences, Chartered status is generally much less important than in the physical sciences.

There are ten QAA benchmark statements in science, mathematics and engineering subjects. They provide a means for the academic community to describe the nature and characteristics of programmes in a specific subject, representing general expectations about the standards for the award of qualifications at a given level and articulating the attributes and capabilities that those possessing the qualification should be able to demonstrate.

Although the chemistry benchmark statement specifies specific subject knowledge, such as 'knowledge of the major types of chemical reaction and the main characteristics associated with them', the biosciences statement, acknowledging that no course has the time to cover everything that is encompassed by the biosciences, instead specifies approaches to the study of subject knowledge likely to be common to all biosciences degree programmes, such as 'engagement with the essential facts, major concepts, principles and theories associated with the chosen discipline'. All the statements also articulate generic and transferable skills that graduates in these subjects should possess.

9.5.4 The impact of developments within Europe

The EU Bologna 3:2:3 structure for bachelor, masters and PhD has implications for the level and breadth of knowledge and understanding expected at the end of each of the three segments, not just overall. The UK approach until relatively recently has been a minimalist response to Bologna, but it is not clear that this continues to be appropriate. The major changes made by France and Germany to their HE systems in response to Bologna may significantly increase the attractiveness of their universities relative to those of the UK. There is a case for seeing Bologna as an opportunity to take a radical look at the overall structure of UK HE. Just because the UK system is closer to the overall Bologna arrangements, this should not be seen as an excuse for delaying an in-depth review.

There is evidence that firms and elite foreign academic research teams have reported that, in general, newly graduated UK PhDs are not as mature or well rounded as their French, German or US counterparts (see, for example, EPSRC 2002).

The UK is currently holding the chair of the Bologna discussions until the London Ministerial Summit meeting in May 2007, and this should be seen as an opportunity for UK HE institutions to become more engaged in the process and to debate how UK HE should proceed.

9.6 What do STM first degree graduates do?

Chapter 6 discusses the available information on the future careers of first degree graduates. There are some highly selective cohort studies, but the only comprehensive information comes from the HESA first destination survey taken six months after graduation. Care has to be taken over the interpretation of this survey, but it is clear that a significant proportion of mathematics, biology, chemistry and physics graduates undertake further study after graduation, although a slightly lower proportion than a decade ago. Fewer engineering and computer science graduates go onto further study. Most chemistry and over 40% of physics graduates undertaking further study are taking a research degree, but much lower proportions of other STM graduates. As would be expected, in chemistry and physics a higher proportion of those graduating with an enhanced first degree go on to further study. Between 15% and 25% of STM graduates undertaking further study are on postgraduate diploma or certificate courses, largely PGCE.

Of those who enter directly into employment, the HESA first destination survey analyses these in terms of both the Standard Industrial Classification and Standard Occupational Classification, and Figures 6.5 and 6.6 show the wide range of careers being followed and the major differences between the various disciplines, which make generic comments difficult. However, from the SOC analysis, assuming that the seven 'professional' SOC categories constitute 'graduate-level' jobs then 45% of engineering & technology graduates, 38% of chemistry, 37% of mathematics and 35% of computer science graduates, 33% of physics graduates and 20% of biology graduates are employed in graduate-level occupations six months after graduation. Within this category there are significant numbers of teaching professionals, most of whom will have undertaken a four year BEd course; the figure will therefore under-report the actual number of people involved, because each BEd graduate will only count half a person towards the particular STM discipline total.

If taken together with full-time further study, the percentages of the total first graduates who responded to the first destinations survey who are in professional posts or undertaking further study six months after graduation are:

Mathematics	47%
Biology	34%
Chemistry	53%
Physics	49%

Also of note is the significant number of chemistry and biology graduates who are classified as science and engineering technicians, less so for physics. This indicates that at that stage after graduation, graduates in chemistry and biology may be employed in analytical or other

technician work in the public or private sectors, possibly initially in sub-graduate posts for which they may be ill-prepared. There are senior analytical and service chemistry and physics posts in both the public and private sectors that require high-quality and well-motivated staff at Foundation Degree/HND/HNC and first degree level. A-level grades and first degree classifications are not necessarily a good guide to suitability for such posts, and some may benefit from more specialist practical training than is common in traditional first degree science courses.

9.7 The quantitative and qualitative demand for physical science and mathematics graduates

It has always proved impossible to assess the quantitative employer demand for particular skills in the timescales that are relevant to changing the HE output. The accelerating changes to the world economic situation just exacerbate this problem. Furthermore, the detailed requirements of an advanced knowledge base are not entirely clear. Arguably the best that can be achieved is to ensure the continuing health of UK universities with a balanced output of first degree graduates with respect to disciplines and across the types of skills that are developed within each of these disciplines. It is essential that there should continue to be significant numbers of students taking disciplines as far as is possible at first degree level, as opposed to joint discipline degrees. Furthermore graduates need to be provided with an education and training that will equip them for a range of graduate posts and to take control of their future continuing professional development, including that necessary to change career direction as the economy evolves.

A starting point for any consideration of future quantitative or qualitative requirements is a knowledge of the present output from the HE system and its impact on the economy. The new HESA data on first destinations have enabled a more detailed analysis of the first destinations from first degree STEM courses than was possible for Roberts review *SET for Success* (Roberts 2002). Although the latter overestimated the number of first degree graduates in science subjects who went directly into STM-related jobs, there is still a significant demand for STM graduates, both for direct employment and for STM careers after further study.

As far as current STEM courses are concerned, there is some evidence that science and engineering graduates still command an earnings premium over their arts, humanities and social science peers. Although there needs to be further analysis of these findings, for example to take account of the premium associated with A-level mathematics, it is probable that quantitative abilities feature highly in the desirable attributes of science and engineering graduates.

9.8 STM first degrees, skills, knowledge and experience

9.8.1 STM courses for those wishing to continue in STM

There is a wide range of career choices for STM first degree graduates wishing to continue within STM, some of which will require further study, such as a PGCE or research degree, and also a range of more generic skills such as communications, team working and a 'self-starting' attitude. As far as STM-related knowledge and skills are concerned, an important issue in the physical sciences and mathematics is what level should be expected at bachelor level and whether for certain careers further study either as an integrated or free-standing masters is generally required.

9.8.2 Work experience and generic skills

Large employers of professional STM graduates in a range of businesses have stressed the importance of work experience, communications and team-working skills. However, it is clear that first and foremost they are seeking highly qualified scientists and mathematicians who have taken their discipline as far as possible at the particular degree level, and that from within that selection they then use the more generic skills to decide whom they will offer posts to. As these generic skills are anyway key to success in any STM professional career, their development should be built into the STM course curriculum.

As far as work experience is concerned, this is one way of acquiring these wider skills, and in signalling interest in a particular career. Unfortunately, universities and individual students have difficulties in finding sufficient employers able to offer suitable work experience. Offering such opportunities may be very costly for some SMEs.

9.8.3 STM courses as preparation for non-professional STM careers

Coupled with the concerns over the development of the BSc/integrated masters courses, there is the question of whether students who are not going to use their degree subject directly in their subsequent professional career are best served by the current BSc honours arrangements. In some cases, clearly graduates who pursue successfully other careers have benefited from the high level of analytical, mathematical and modelling skills that such courses offer. Nevertheless, some graduates may prefer the option of 'practical-light' third years, general science degrees, or the 'Science Greats' courses (as pioneered by Jevons at Manchester in the 1960s). However, such options or new courses need to provide the depth necessary to maintain the quality of the educational experience.

As can be seen from the overall position set out in chapter 5, there is a wide range of courses within the physical and biological sciences, many pioneered within post-1992 universities, which also introduce scientific concepts. However, for some of the most able students, the discipline of studying a traditional subject in either STM or the humanities as far as can be achieved in a first degree course is a worthwhile educational experience, even if the subject is not directly relevant to the future career pursued. Furthermore, it is important to maintain student numbers in the main science disciplines in order to retain the potential supply flexibilities. This may therefore point to exploring the possibilities for allowing for a range of choices in the final year of these courses, rather than the design of completely new courses.

9.9 Further work

Our analysis of these data has highlighted several important policy issues, some of which we shall be considering further in the next phase of the project. At the start of this second phase we issued a call for evidence, in which we particularly invited comments on the following issues:

(a) The nature of the benefits to a student that accrue from studying an STM subject at HE level, whatever their future occupation.

(b) The demand for STM graduates from the economy and wider society, and how this demand is changing.

(c) The quantity of those graduating at all levels of the HE system, and the quality, depth and breadth of their educational and training experiences.

(d) The length of time HE studies should take, and how that time should be broken down (with reference to the Bologna proposals to standardise the structure of HE across Europe).

(e) The current discipline boundaries and whether a general science first degree option could be appropriate.

(f) The changes to the skills, knowledge and experience of those entering the HE system and how the HE system can accommodate such changes.

(g) The need to allow students to be flexible in their choices of occupation as they gain their qualification and afterwards.

(h) The increasing number of students who choose to study later in their lives, and/or part-time, and/ or have geographic limitations on where they can study.

(i) The financial impact upon students who undertake HE study.

(j) The impact, on the UK, of international flows of students and STM professionals.

(k) The developments in HE and economic policy inside and outside the UK and how the HE system can accommodate these changes.

We are now studying the responses and deciding on the areas to be covered in this second phase of the study, on which we expect to report in the autumn of 2007. The findings of this first phase will be a major input to this forthcoming work.

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Detailed subject information

In this report we have, where possible, used the original sources of data. More detailed information on individual subjects can be found, for example, at the websites of the following organisations:

- The Engineering and Technology Board: www.etechb.co.uk/pdf/Engineering_UK_2005.pdf

- Institute of Physics: www.iop.org/Our_Activities/Science_Policy/Statistics/index.html

- Royal Society of Chemistry: www.rsc.org/images/SummaryOfAll_tcm18–38686.pdf

Acronyms

ABPI	Association of the British Pharmaceutical Industry
API	Age Participation Index
DfES	Department for Education and Skills
DTI	Department for Trade and Industry
GDP	Gross Domestic Product
GERD	Gross Expenditure on Research & Development (OECD defined)
GTTR	Graduate Teacher Training Registry
HE	Higher Education
HEFCE	Higher Education Funding Council for England
HEIPR	Higher Education Initial Participation Rate
HESA	Higher Education Statistics Agency
HND/HNC	Higher National Diploma/Higher National Certificate
HMT	Her Majesty's Treasury
ICT	Information and Computer Technology
IOB	Institute of Biology
IOP	Institute of Physics
ISCED	International Standard Classification of Education
ITT	Initial Teacher Training
JCQ	Joint Council for Qualifications
NSF	US National Science Foundation
OECD	Organisation for Economic Co-operation and Development
OSI	Office of Science and Innovation
PGCE	Postgraduate Certification in Education
QAA	Qualifications Assurance Agency for HE
QCA	Qualifications and Curriculum Authority
RAE	Research Assessment Exercise
RAEng	Royal Academy of Engineering
R&D	Research and Development
RSC	Royal Society of Chemistry

SEMTA	Sector Skills Council for Science, Engineering & Manufacturing Technology
SIC	Standard Industrial Classification
SME	Small and medium-sized enterprise
SOC	Standard Occupational Classification
SQA	Scottish Qualifications Authority
STM	Science, Technology and Mathematics
STEM	Science, Technology, Engineering and Mathematics
TDA	Training and Development Agency for Schools
TRAC	Transparent Approach to Costing
UCAS	Universities and Colleges Admissions Service
UUK	Universities UK

Annex 1 Higher Education Working Group and Secretariat

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

Professor John Wood FREng, Chief Executive, CCLRC Rutherford Appleton Laboratory

Secretariat

Ms Sara Al-Bader (to October 2005)

Ms Sarah Revell

Dr Keith Root

Ms Alice Sharp Pierson (from January 2006)

Annex 2 Higher Education Institutional Groupings

As at August 2005, there were 125 university institutions in the UK, counting the colleges of the University of Wales and the University of London separately (if Wales and London are counted as single institutions the total was 96). Within this total, several different groupings exist.

Pre-1992 universities

Institutions that were regarded as having the status of a university before the provisions of the Further and Higher Education Act 1992 came into force. These institutions do not function as an organised group; some belong to other institutional groupings such as the Russell Group.

Post-1992 universities

Institutions that have gained the status of a university after the provisions of the Further and Higher Education Act 1992 came into force. Again, these institutions do not function as an organised group but some belong to other institutional groupings.

The Russell Group

The Russell Group is an association of 19 major research-intensive universities of the United Kingdom which was formed in 1994 at a meeting convened in the Hotel Russell, London. The aims and objectives of the Russell Group are 'to promote the interests of Universities in which teaching and learning are undertaken within a culture of research excellence, and to identify and disseminate new thinking and ideas about the organisation and management of such institutions.'

The following is a list of those institutions that had university status before and after 1992. Russell Group members are marked with an asterisk within the list of pre-1992 universities.

Pre-1992 Universities England	Post-1992 Universities England
Aston University	Anglia Ruskin University
University of Bath	Bath Spa University
University of Birmingham*	University of Bedfordshire
University of Bradford	University of Bolton
University of Bristol*	Bournemouth University
Brunel University	University of Brighton
University of Cambridge*	Canterbury Christ Church University
City University	University of Central England in Birmingham
Cranfield University	University of Central Lancashire
University of Durham	University of Chester
University of East Anglia	University of Chichester
University of Essex	Coventry University
University of Exeter	De Montfort University
University of Hull	University of Derby
Keele University	University of East London
University of Kent at Canterbury	University College Falmouth
Lancaster University	University of Gloucestershire
University of Leeds*	University of Greenwich
University of Leicester	University of Hertfordshire
University of Liverpool*	University of Huddersfield
University of London:	Kingston University
Birkbeck College	Leeds Metropolitan University
Goldsmiths College	University of Lincoln
Imperial College of Science, Technology & Medicine*	Liverpool Hope University
King's College London*	Liverpool John Moores University
London School of Economics & Political Science*	University of The Arts, London
Queen Mary and Westfield College	London Metropolitan University

Royal Holloway, University of London	London South Bank University
University College London*	University of Luton
Loughborough University of Technology	Manchester Metropolitan University
University of Manchester*	Middlesex University
UMIST (now part of University of Manchester)	University of Northampton
University of Newcastle upon Tyne*	University of Northumbria at Newcastle
University of Nottingham*	Nottingham Trent University
The Open University	Oxford Brookes University
University of Oxford*	University of Plymouth
University of Reading	University of Portsmouth
University of Salford	Roehampton University
University of Sheffield*	Sheffield Hallam University
University of Southampton*	Southampton Solent University
University of Surrey	Staffordshire University
University of Sussex	University of Sunderland
University of Warwick*	University of Teesside
University of York	Thames Valley University
	University of West of England, Bristol
Wales	University of Westminster
University College of Wales Aberystwyth	University of Winchester
University College of North Wales Bangor	University of Wolverhampton
University of Wales College of Cardiff*	University of Worcester
St David's University College of Lampeter	
University College of Swansea	**Wales**
University of Wales College of Medicine	University of Glamorgan
	The University of Wales, Newport
Scotland	
University of Aberdeen	**Scotland**
University of Dundee	University of Abertay Dundee
University of Edinburgh*	Glasgow Caledonian University
University of Glasgow*	Napier University
Heriot Watt University	University of Paisley
University of St Andrews	Robert Gordon University
University of Strathclyde	
University of Stirling	
Northern Ireland	
University of Ulster	In addition there are several university colleges and
Queens University of Belfast	institutes of HE.

Annex 3 Scottish Highers

Figure A3.1. Scottish Highers entries in science and mathematics, 1991–2006 (Scottish Qualifications Authority).
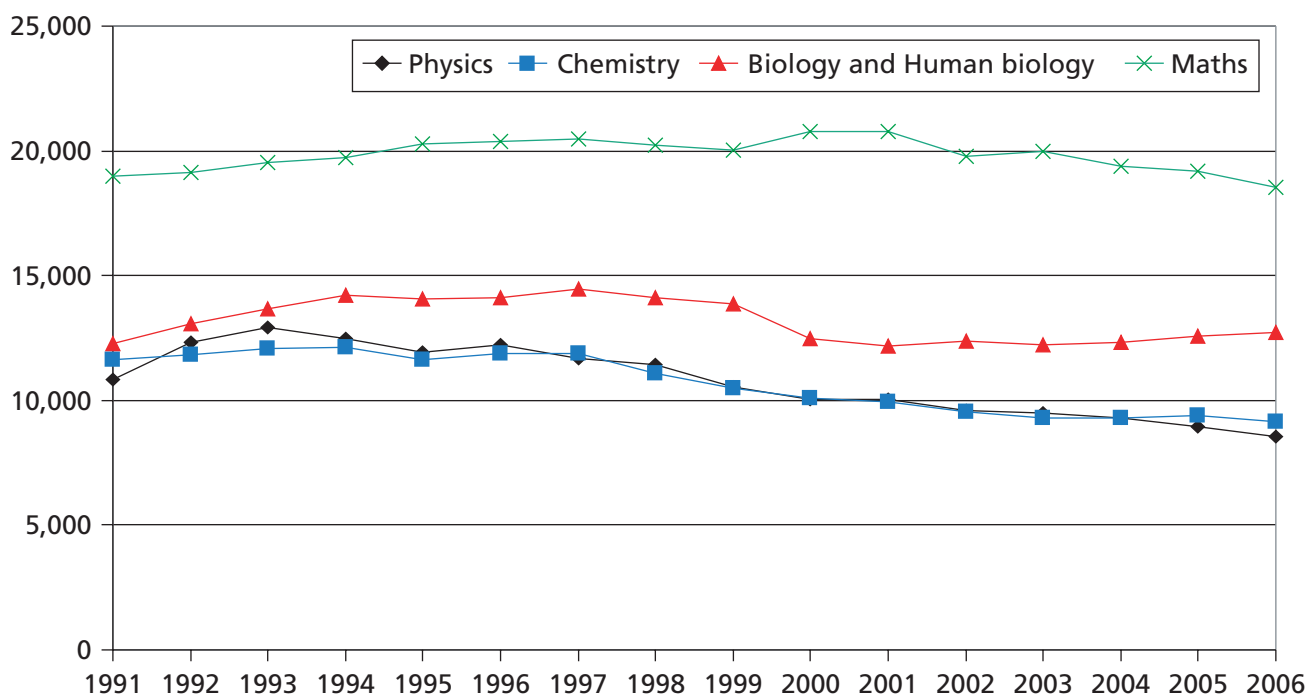
Annex 4 Distribution of first degree course provision by type of institution

Table A4.1. Distribution of first degree course provision by type of HE institution (UCAS course listings 2006). These data are an expanded analysis of those presented in Figure 5.1.

	BSc course only				Integrated masters and BSc course or integrated masters only			Total
	Russell Group	Other pre-92	Post-92	FE colleges	Russell Group	Other pre-92	Post-92	
Chemistry	0	2	6	0	18	15	6	47
Physics	0	2	2	0	17	20	3	44
Biology	13	23	20	0	1	2	0	59
Maths	2	10	16	0	15	18	2	63
Statistics	5	6	6	0	1	1	0	19
Biochemistry	12	22	14	0	4	1	0	53
Microbiology	10	9	11	0	1	0	0	31
Genetics	10	9	3	0	2	0	0	24
Geology	3	5	8	0	7	1	1	25
Mechanical engineering	0	2	20	0	17	17	5	61
Electronic and electrical engineering	0	4	20	0	16	15	2	57
Civil engineering	3	16	0	0	14	11	5	49
Computer science	8	26	43	2	8	5	2	94
Sports science	3	12	41	3	0	0	0	59
Psychology	14	28	49	3	0	0	0	94

Annex 5 Distribution of first degrees achieved by institution type

Table A5.1. Distribution of first degrees achieved by institution type (HESA data). This is an expansion of data presented in Figure 5.2.

2004/05	Number of first degrees obtained (UK)	Percentage in Russell Group institutions	Percentage in other pre-1992 institutions	Percentage in post-1992 institutions
All degrees	**306,365**	**23**	**26**	**51**
Biological sciences	**27,200**	**24**	**32**	**44**
Biology	4,585	32	34	34
Psychology	11,450	17	39	44
Sports science	5,605	5	20	75
Molecular biology, biophysics & biochemistry	1,850	56	32	11
Physical sciences	**12,530**	**42**	**32**	**26**
Chemistry	2,715	46	29	25
Physics	2,255	61	35	4
Forensic & archaeological science	740	22	20	57
Physical & terrestrial geographical and environmental sciences	4,335	30	30	40
Mathematical sciences	**5,270**	**48**	**38**	**14**
Maths	4,590	50	36	13
Statistics	385	47	34	19
Computer science	**20,095**	**12**	**24**	**65**
Computer science	13,445	13	25	62
Information science	5,265	7	21	72
Artificial intelligence	100	60	35	5
Engineering and technology	**19,575**	**28**	**24**	**48**
Electronic and electrical engineering	5,630	25	25	50
Mechanical engineering	3,410	31	25	44
Civil engineering	2,510	32	25	43

Annex 6 Newly commissioned HESA statistics

Background

The Higher Education Statistics Agency (HESA) is the official agency for the collection, analysis and dissemination of quantitative information about HE. Most analyses of trends in student and graduate numbers are based on data published by HESA in its annual *Students in HE institutions* volumes (HESA 1997–2006a). However, there are several factors which make year-to-year comparison of the data published by HESA problematic. In particular, there were major changes to the way in which students were counted and classified by subject of study from 2002/03 onwards.

To obtain a more time-consistent dataset, the Society and the Office of Science and Innovation (OSI) jointly commissioned a revised set of data from HESA for the period 1994/95–2004/05. These new data series, as far as possible, remove the major inconsistencies in the way in which student were counted pre- and post-2002/03 and allows continuous time-series data to be constructed.

Changes to HESA data

The major changes in HESA methodology between 2001/02 and 2002/03 onwards are discussed below.

Subject of study: HESACODE to JACS

The first major change was the introduction of the Joint Academic Coding System (JACS) in 2002/03 to categorise subjects of study, aligning the coding systems of HESA and UCAS and replacing the HESACODE-system previously used by HESA. JACS and HESACODE, and the subject areas defined in terms of them, are similar in appearance and have much in common, but they are by no means identical.

Although this change in subject categories does not affect all science subjects, it was impossible for HESA to remove this discontinuity in the data. Where subject names have changed or mappings between pre- and post-2002/03 subject categories have been used in the analysis presented in this report to maintain the most consistent data series these are listed at the end of this annex.

Split programmes: allocation to apportionment

The second major change relates to the way in which degree courses spanning more than one subject are counted. Before 2002/03, students on a split programme were allocated to a single subject area, or to a 'combined' subject category. From 2002/03 onwards, students have been apportioned between the components of a split programme and as a result most of the students previously allocated to a 'combined' category are distributed across specific JACS-based subject areas. The apportionment algorithm is as follows: a balanced two subject programme is treated as comprising two components of one half weight; a major/minor two subject programme is treated as comprising a two thirds weight major component and a one third weight minor component; and a three subject programme is treated as comprising three components of one third weight.

Additionally, before 2002/03 all Initial Teacher Training (ITT) students were allocated to the 'Education' subject category regardless of any additional subjects studied. From 2002/03 onwards, primary school ITT students are apportioned entirely to 'Education', but other ITT students are apportioned with one half weight to 'Education' and the remaining one half to their subject specialism.

To remove this discontinuity in the way in which students are counted, the OSI/Royal Society commissioned data from HESA apportions the pre-2002/03 HESACODE data using the JACS apportionment methodology as closely as possible. This eliminates one of the major causes of discontinuity in the data published in the annual *Students in HE institutions* volumes (HESA 1997–2006a).

Subject trends

The difference that the newly commissioned HESA data make to apparent trends in science and maths subjects is shown in Figure A6.1, where the broken lines represent the data previously published by HESA (HESA 1997–2006a) and the unbroken lines represent the revised data series which use the post-2002/03 apportionment methodology (OSI/Royal Society commissioned data). From this, it is clear that the large apparent rise in student numbers in subjects such as maths and to a lesser extent biology are actually just the consequence of the change in the way that HESA have classified students on dual honours courses since 2002/03.

Figure A6.2 shows the corresponding decrease in teacher training students, which has come from the partial reassignment of secondary ITT students to their specialist subject. The number of students on ITT courses appears to have decreased by less than half because those training to teach in primary schools remain wholly assigned to the teacher training category.

Subject mappings

Where subject names have changed, post-2002/03 subject category names have been used in the main body of this report.

Where two HESACODE categories have been combined to form a single JACS category (eg Electrical Engineering

Figure A6.1. First degrees obtained by students of all domiciles, 1995/96–2004/05, where the broken lines represent data published in the HESA reference volumes and the solid line represents the revised consistent data series commissioned by the OST and the Royal Society.
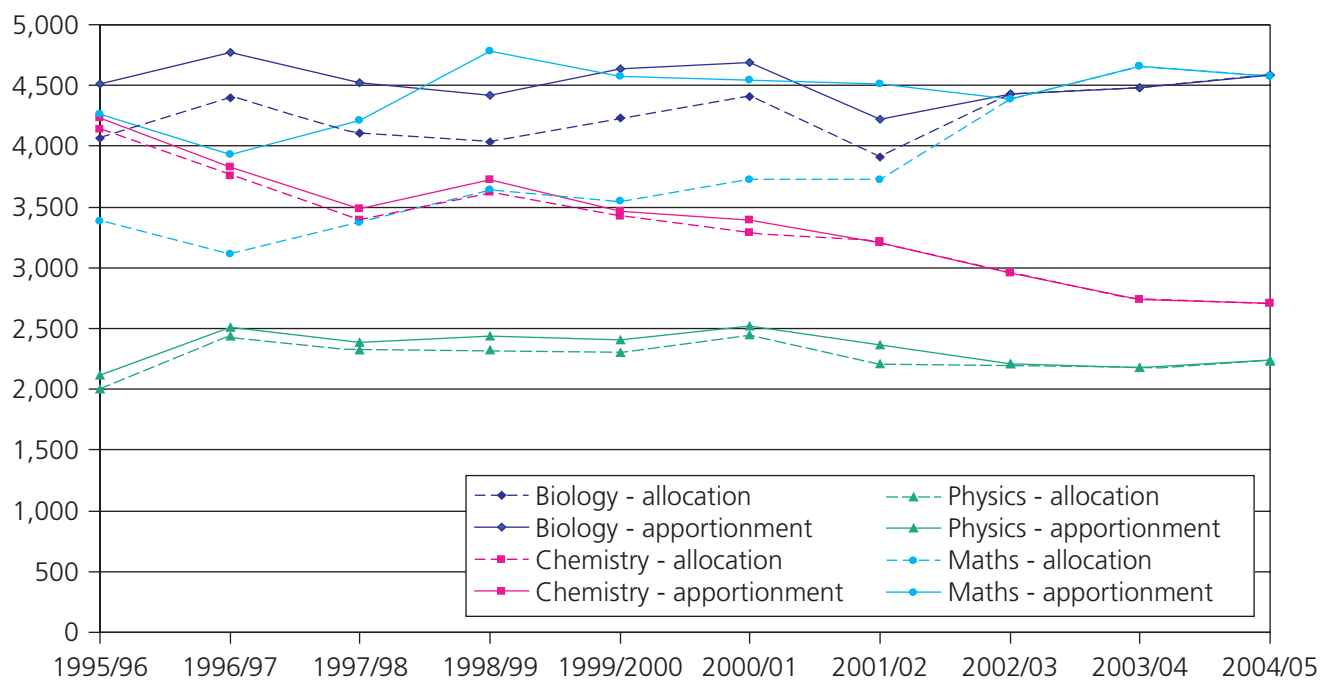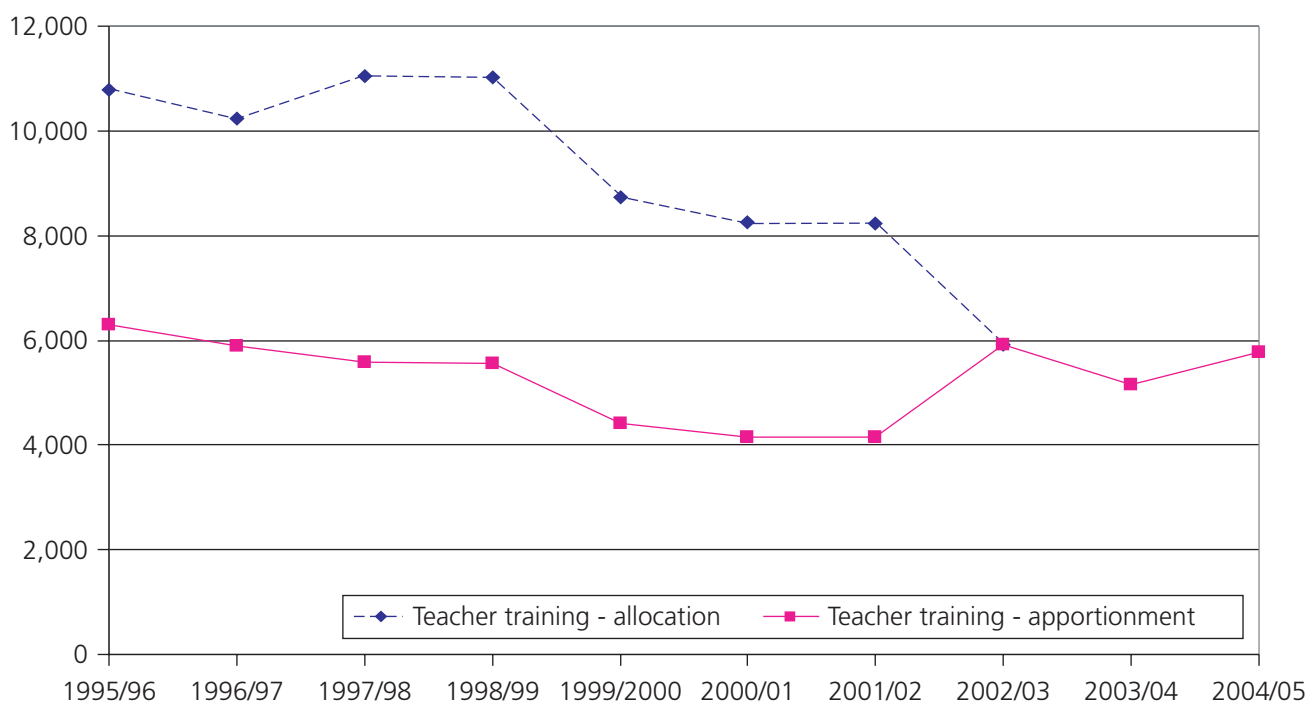

Figure A6.2. First degrees obtained in teaching by students of all domiciles, 1995/96–2004/05, where the broken lines represent data published in the HESA reference volumes and the solid line represents the revised consistent data series commissioned by the OST and the Royal Society.

and Electronic Engineering becoming Electronic and Electrical Engineering), the two pre-2002/03 categories have been added together to provide consistency with the post-2002/03 category.

Where one HESACODE category has been split to form two JACS categories (eg 'Other biological sciences' becoming 'Others in biological sciences' and 'Sports science'), the HESACODE category has been used from 1994/95 to 2001/02 and the JACS categories from 2002/03 onwards.

Biological sciences

JACS category (2002/03 onwards)	HESACODE category (1994/95–2001/02)
Molecular biology, biophysics & biochemistry	Molecular biology and biophysics
	Biochemistry
Psychology	Psychology (not solely as social science)
	Psychology (without significant element of biological science)
Others in biological sciences	Other biological sciences
Sports science	

Physical sciences

Forensic & archaeological Science	Archaeology (as a science)
Ocean Sciences	Oceanography
Physical & terrestrial geographical & environmental sciences	Geography studies as a science
	Environmental science and other physical sciences

Engineering and technology

Electronic and Electrical Engineering	Electrical engineering
	Electronic engineering

Annex 7 Graduate premium

Table A7.1. First destination of students who graduated in 2002–03 and average starting salary, HESA 2002–03 (Times Higher Education Supplement, 26 May 2005).

	Further full-time study	Graduate job		Non-graduate job		Unemployed	Average starting salary (£)
		Not Studying	Studying	Not Studying	Studying		
Medicine	8	89	2	0	0	1	31,353
Dentistry	1	81	17	1	0	0	26,236
Chemical engineering	20	48	7	15	2	9	21,049
Veterinary medicine	16	70	3	7	1	2	20,765
Civil engineering	8	67	9	10	1	3	19,388
General engineering	14	48	7	21	1	10	19,327
Mechanical engineering	11	50	5	22	2	10	18,831
Aeronautical and manufacturing engineering	12	45	6	24	2	11	18,589
Electrical and Electronic Engineering	13	42	5	24	2	14	18,085
Education	9	70	3	14	2	3	17,548
Computer Science	10	44	4	26	3	13	17,424
Food science	12	61	5	15	2	4	17,272
Anatomy and physiology	19	56	5	15	1	4	17,060
Mathematics	25	29	10	26	3	8	16,887
Materials technology	15	37	4	33	2	9	16,861
Subjects allied to medicine	8	68	9	11	2	3	16,806
Chemistry	36	32	4	19	2	7	16,670
Physics and Astronomy	36	21	6	24	2	11	16,104
Geology	27	29	2	31	2	8	15,172
Anthropology	16	31	4	35	3	11	15,090
Architecture	14	57	16	8	1	4	15,075
Pharmacology/pharmacy	12	55	21	8	1	3	14,977
Geography	20	32	4	35	3	7	14,722
Agriculture and forestry	9	40	6	38	2	5	14,302
Biological sciences	28	28	4	29	2	8	14,279
Psychology	17	27	6	39	5	6	14,215
Average across all subjects	**16**	**39**	**5**	**29**	**3**	**7**	**16,485**