2 SCHOOL AND FURTHER EDUCATION

Summary of issues

The experiences of pupils while in school and further education are crucial to their subsequent education and training, and to their careers. There is much concern that, during their time in school and further education, pupils are turning away from the study of science, technology, engineering and mathematics. This is a significant factor in explaining the difficulties experienced by employers in recruiting people with high level science and engineering skills.

This chapter explores these issues and finds that whereas standards in schools are rising overall, there are worrying trends in the subjects chosen by pupils, with significantly fewer choosing to study mathematics and the physical sciences at higher levels. For example, between 1991/92 and 1999/00 the numbers taking A-levels in physics and mathematics fell by 21 per cent and 9 per cent respectively. The Review's analysis suggests that there are a number of deep-seated issues that need to be addressed in order to improve the UK's future supply of high level science and engineering skills. These issues include:

- shortages in the supply of science and mathematics teachers;
- out of date scientific laboratories and equipment;
- the ability of courses to inspire and interest students; and
- a number of other factors affecting students' motivations to study science, technology, engineering and mathematics at higher levels (for example, careers advice).

The chapter considers the effect of steps already taken to address these issues, before going on to make recommendations for further improving pupils' learning experiences in science, mathematics, information and communication technology (ICT), and design and technology.[35] The majority of these recommendations fall to the Government to implement and will require additional resources. However, the Government will need to work closely with teachers and others in and outside schools and further education in order to deliver these improvements in a way that brings about the substantive change needed without disrupting pupils' education or adding unnecessarily to teachers' workloads.

These recommendations are intended to improve the supply of science and engineering skills to the economy while also widening access to higher education and increasing the ability and flexibility of schools to respond to the challenges facing them in the 21st century.[36]

[35] Although achievement in a range of subjects is important in developing science and engineering skills, particular emphasis is given to the study of science and mathematics, and also to design & technology (D&T) and ICT.

[36] Many of the recommendations made on issues relating to secondary schools also apply to further education. For ease of reading, the recommendations are phrased in terms of secondary schools, but the intention of the Review is that the further education sector should be covered, wherever appropriate, by these recommendations.

Education in England[37]

2.1 Subject-oriented education for most pupils in England starts at the age of five in primary school, and continues until the age of eleven, at which time they move on to secondary school.[38] Pupils are required, in nearly all cases, to attend school until the age of sixteen, at which time they take a number of GCSEs (commonly in around eight subjects).

2.2 The National Curriculum sets out the statutory framework for education in England up to the age of 16, and is structured around four 'Key Stages':[39]

- Key Stage 1 (5 to 7 year olds);
- Key Stage 2 (7 to 11 year olds);
- Key Stage 3 (11 to 14 year olds); and
- Key Stage 4 (14 to 16 year olds).

Primary school education

Under the National Curriculum, students are taught the 'core' subjects of mathematics, ICT, English and science from the age of five. The Government focuses its assessment of pupils' academic achievements in primary schools on their scores in 'Key Stage' tests at the ages of 7 and 11. Pupils also study a number of 'Foundation' subjects: geography, history, D&T, art, music and physical education as well as religious education, and personal, social and health education and citizenship. Key Stage 1 assessments (taken by 7 year-olds) focus on English and mathematics, whereas, attention in the Key Stage 2 assessments (taken by 11 year-olds) is on achievements in English, mathematics, and science.

2.3 Education is not compulsory after the age of 16, but around 60 per cent of pupils will study full time for AS-levels, A-levels and/or more vocational qualifications, such as GNVQs. This generally occurs in a school sixth form or a further education college.

[37] This report is for the UK Government and the chapter therefore focuses on school and further education in England. However, comparisons with particular aspects of education in Scotland, Wales and Northern Ireland are made where appropriate.

[38] An alternative route followed by a minority of students is to attend a 'middle' school between, for example, the ages of 7 and 14. However, this report focuses on the route described in the main text, which is followed by the vast majority of students.

[39] Key Stages and tests are not specifically age-related. Pupils can pass through them at a pace judged appropriate by their teachers. Most pass through at the ages set out above.

Secondary and further education

Between the ages of 11 and 16 assessment of students occurs at 14 with the Key Stage 3 tests and the GCSEs (Key Stage 4), generally at 16. The National Curriculum – which specifies the areas that must be studied – states that at both Key Stage 3 and Key Stage 4, pupils must study English, mathematics, science, design and technology (D&T), ICT, a foreign language, physical educataion, and citizenship. History, geography, art and music are also compulsory at Key Stage 3, although not at Key Stage 4. There are also a great many optional subjects (e.g. economics) that may be taken in addition to the compulsory subjects.

After taking their GCSEs at the age of 16, pupils can study a wide range of academic and vocational A-levels and AS-levels, as well as other vocational qualifications such as Vocational Certificates of Education (VCEs). Pupils now have much more choice over the range of subjects open to them, reflecting the Government's aim of increasing participation in post-16 education by (among other measures) helping students to find courses that appeal to them. Under the current arrangements students are encouraged to study combinations of academic and vocational courses – such as AS-level General Certificates of Education (GCEs) and VCEs (3 units), A-level GCEs and VCEs (6 units) and double award advanced level VCEs (12 units) to take them up to a total of around 21 units. There are also a range of other vocational courses that can be taken – for example, Advanced Modern Apprenticeships (AMAs).

Proposals aimed at reforming the 14-19 phase of education were recently announced in the Green Paper, *14-19: extending opportunities, raising standards.* Under these proposals, which aim to increase flexibility, appeal, choice and participation in this phase of education, pupils would no longer have to take D&T (or a foreign language) past the age of 14. Pupils would also work towards gaining a "Matriculation Diploma" at the age of 19 – an overarching award incorporating their subject qualifications (e.g. A-levels) and also recognising activities like voluntary work.

Mathematics and science in the National Curriculum

2.4 The Review takes particular interest in mathematics and science education in schools and further education (since these courses are in many cases a prerequisite for higher study in mathematics, engineering and the physical sciences). Until Key Stage 4 nearly all pupils follow the same mathematics and sciences courses, which are aimed at providing a strong foundation of mathematical and scientific principles, while also relating these principles to pupils' experiences outside the classroom. At Key Stage 4, pupils face a number of course choices in both mathematics and science, as set out in the box below. These mathematics and science courses are based on the National Curriculum, which is set by the Qualifications and Curriculum Authority (QCA).

Science and mathematics education at Key Stage 4

Under the National Curriculum, science study in physics, chemistry and biology is compulsory up to the completion of Key Stage 4. Pupils in most schools comply with this through taking a 'double award' science GCSE course, which covers all the major sciences (biology, chemistry and physics).

The aim of the double award is to provide a broad and balanced education for all at GCSE level in less time than would be needed should the pupil study all three sciences. Schools can still allow their pupils to comply with the National Curriculum through taking all three single sciences at GCSE. However, the double award has become dominant for science at Key Stage 4. Schools that persist with three separate GCSEs in science tend to be in the independent sector, although pupils in some maintained schools (for example, some grammar schools) do take individual sciences.

As an alternative to taking the three separate science GCSEs or the double award, some students take a 'single award' in science, covering biology, physics and chemistry but in less breadth. However, these students tend to have reason to spend more time on other subjects.

For mathematics at Key Stage 4, there are three course options available to students: 'Foundation', 'Intermediate' and 'Higher'. Pupils intending to study mathematics at A-level take the Higher course, which is the course required in order to receive a grade A or A*.

2.5 After the age of 16, pupils have a wide range of subjects and course types available to them. These range from the more academic A-level and AS-level courses to the more vocational VCEs and Advanced Modern Apprenticeships. Historically, the main qualifications required by universities for science and engineering degree courses have been A-levels in subjects such as mathematics, further mathematics, physics, chemistry, biology and design and technology. This is likely to continue for some time, although the trend is for pupils entering higher education increasingly to have a wider range of qualifications, including AS-levels and more vocational qualifications.

Further and vocational education

2.6 It is important to consider the roles of both further education colleges and schools in the supply of students to higher education. Nearly one-third of those studying A-levels are doing so in further education colleges, and many of the same issues face both schools and further education colleges. The chapter does not, therefore, consider school education and further education separately, in line with the Government's wish to break down the barriers and the distinctions between school and further education. However, where problems specific to either school or further education exist, these are considered explicitly.

2.7 The Review consulted on whether vocational study is a recognised route for becoming a leading scientist or engineer. The consultation confirmed that although there are cases of individuals who do follow this path, it is not an established route. However, Advanced Modern Apprenticeships increasingly offer a route for young people to progress beyond 'Level 3' (A-level equivalent standard). Until the introduction of AMAs, pupils studying for vocational qualifications in science, technology, engineering and maths tended to fulfil what might traditionally be described as a technician function. For this reason, and given the Review's remit focused on the supply of high-level science and engineering skills, the data presented in this chapter tend to focus on those pupils studying for academic qualifications, such as A-levels.

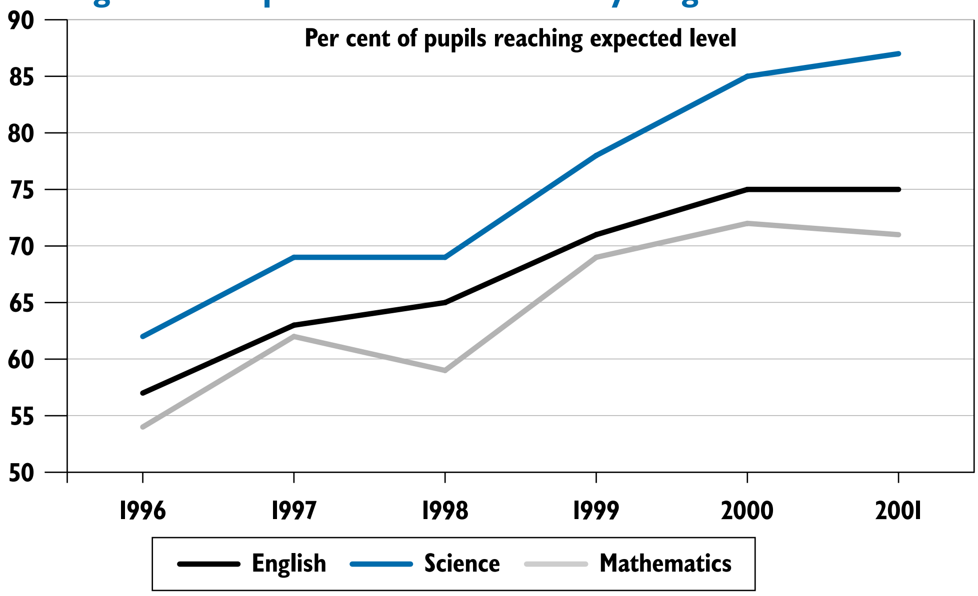
2.8 However, pupils are increasingly likely to take a mixture of academic and vocational qualifications; the current boundary between academic courses and vocational courses is also likely to become increasingly blurred; and vocational routes and courses are likely to become increasingly important if the Government is to meet its target of 50 per cent participation in higher education. The chapter's recommendations are therefore designed to apply, where relevant, to both academic and vocational education.

Pupils' achievements in science, mathematics, D&T and ICT

2.9 Recent years have seen steady improvements in pupil attainment at nearly every level and in nearly every subject. These improvements (see Figure 2.1 and Figure 2.2) reflect the impressive efforts of pupils and teachers, coupled with the new investment in schools in recent years, and the success of initiatives such as the Key Stage 2 literacy and numeracy strategies.

2.10 Figure 2.1 presents trends in the proportion of pupils reaching the required standard (Level 4) in Key Stage 2 assessments. It demonstrates that over the last five years there have been steady improvements in mathematics, English and science. The Government's target is that 85 per cent of all pupils should reach the expected level in mathematics and English by 2004.

Figure 2.1: Pupils' achievements in Key Stage 2 examinations



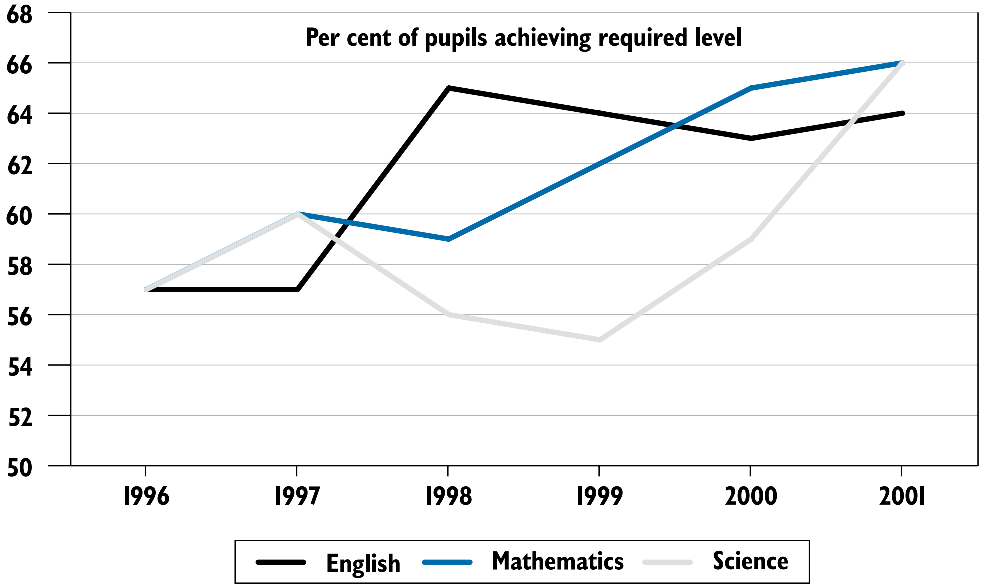
Source: DfES.

2.11 The Government has placed considerable emphasis on boosting pupils' achievements at Key Stage 2, through initiatives such as the national numeracy strategy[40] introduced in the autumn of 1999. However, more effort is needed both to bring pupil's achievements in mathematics up to the levels seen in English and to close the attainment gap between the lowest and highest performing pupils. For example, in over a third of all local education authorities in England, pupils' average attainment levels in the Key Stage 2 mathematics tests are more than ten percentage points below the minimum performance target for 2004. The Review encourages the Government to ensure that policy increasingly enables those pupils currently underperfoming to reach their full potential, so as not only to widen their lifetime opportunities but also to broaden the potential stock of candidates for science and maths at later stages of the education process.

2.12 Pupils' achievements in Key Stage 3 examinations are also encouraging, although the story is somewhat mixed, as shown in Figure 2.2.

2.13 Figure 2.2 shows that although the proportions of pupils reaching the required standard in English, mathematics or science at Key Stage 3 has risen over the last five years, the increases have not been as steady nor as impressive as at Key Stage 2. The Review therefore, welcomes the Government's national Key Stage 3 strategy, which aims to build on the progress that pupils have made at primary school in this critical phase of education.

Figure 2.2: Pupils' achievements in Key Stage 3 examinations



Source: DfES.

[40] The national numeracy strategy introduced a daily 45-60 minute mathematics lesson in primary schools, in which oral and mental work feature strongly, supported by regular mathematical activities for students to do at home. Teachers receive extensive training and guidance to support them in delivering the strategy.

Key Stage 3 National Strategy

The new Key Stage 3 strategy aims to raise expectations and ensure that pupil progress continues smoothly into secondary education. Evidence from OFSTED and other sources suggests that the Key Stage 3 results have been too variable. There is a perceived lack of pace in pupils' education between the ages of 11 and 14, causing some children to lose motivation. There is a strong need to strengthen the early years of secondary education so that the progress gained at Key Stage 2 is not lost. Key elements of the Key Stage 3 Strategy include:

- supporting pupils who start secondary school below the level expected for their age in English and mathematics with programmes to help them catch up with their peers early on. The strategy also caters for more able learners as well, and aims to promote higher standards for all pupils;
- professional development of teachers, with training and support materials which promote direct teaching, interactive learning and strategic management, as well as strengthening teachers' subject knowledge;
- strengthening transition this year from Key Stage 2 to 3, with initiatives starting in primary schools and school holiday initiatives such as summer schools or Saturday classes, as well as catch-up programmes;
- the extensions of the literacy and numeracy strategies into the early years of secondary education through improved teaching and learning of English, mathematics, literacy and numeracy across the curriculum;
- plans to raise standards in science, teaching and learning in the foundation subjects and in ICT, to be introduced nationally from 2002; and
- introduction of targets for Key Stage 3:
  - 75 per cent to achieve Level 5 in mathematics, English and ICT; 70 per cent in science by 2004;
  - 85 per cent to achieve Level 5 or above in English, mathematics and ICT; 80 per cent in science by 2007; and
  - as a minimum performance target, at least 65 per cent to achieve Level 5 and above in English and mathematics; 60 per cent in science in each Local Education Authority by 2004.

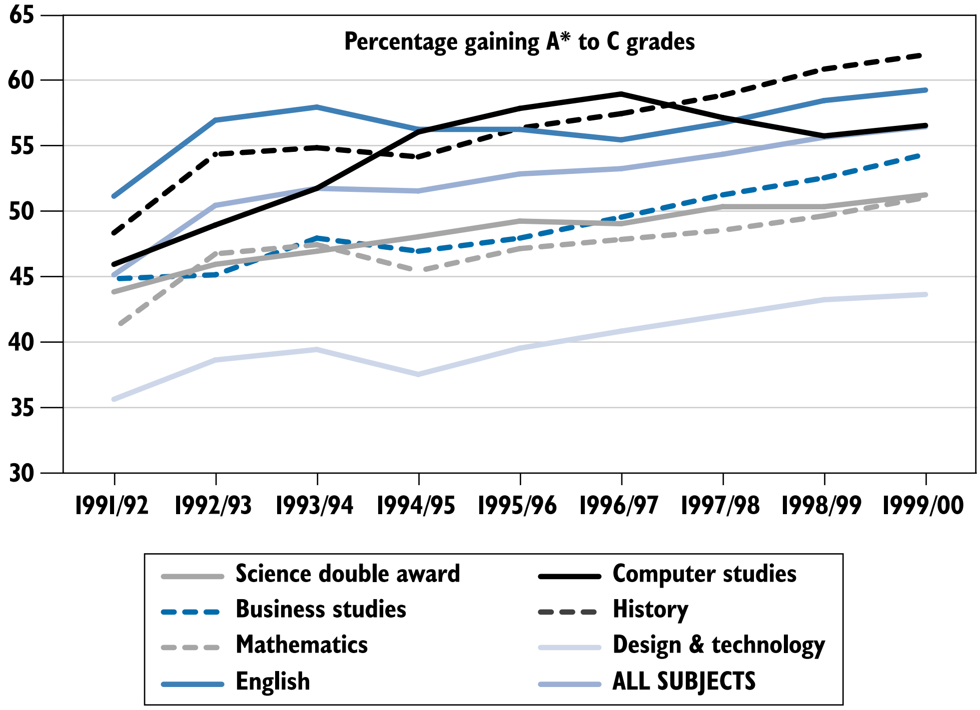
The Key Stage 3 strategy aims to raise standards of all 11 to 14 year olds so that by the time they move on to Key Stage 4 they have:

- reached acceptable standards of attainment (Level 5 or above in their Key Stage 3 National Curriculum tests) in the basics of English, mathematics, science and ICT;
- benefited from a broad curriculum, including studying each of the National Curriculum subjects; and
- learned how to reason, think logically and creatively and to take increasing responsibility for their own learning.

2.14 In line with the progress seen at Key Stages 2 and 3, pupils' achievements in GCSE examinations have also improved steadily in the second half of the 1990s (Figure 2.3). Computer studies is the only subject that does not show this steadily increasing profile.

2.15 It should be noted that there is an annual debate at the time the GCSE and A-level figures are released as to whether standards have indeed risen. The popularity of this annual debate reflects the difficulty in proving or disproving this hypothesis beyond all doubt. However, in the view of both OFSTED and the Qualifications and Curriculum Authority (QCA), these trends do generally represent increasing levels of student attainment.

Figure 2.3: Pupils' achievements in selected GCSE examinations, 1991/92 to 1999/00

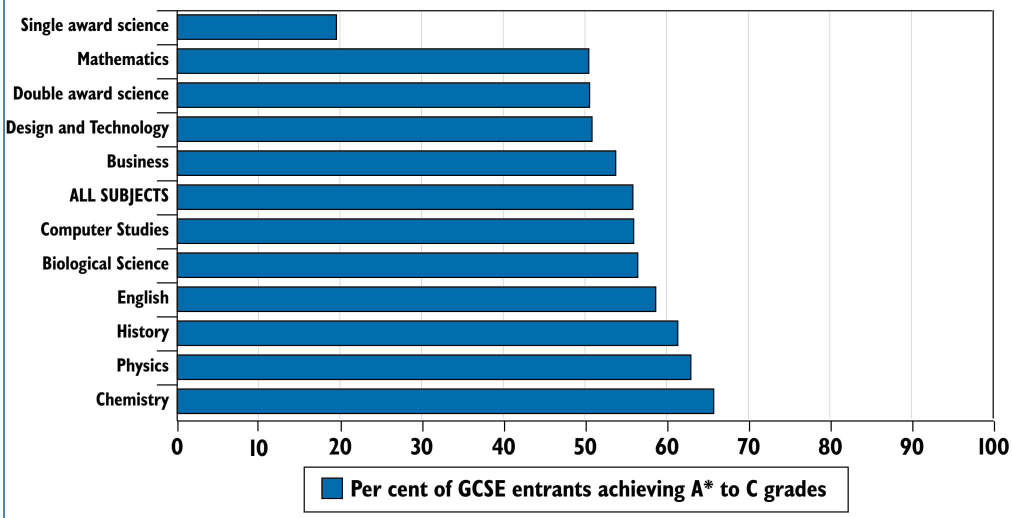


Source: DfEE/DfES (various years) Statistics of Education: Public Examinations GCSE and GCE in England.

2.16 As Figure 2.3 suggests (and as is clarified in Figure 2.4), there are considerable differences in the achievements of pupils in different subjects, with a lower proportion of pupils achieving grades A*-C in mathematics and the sciences than in other subjects.

2.17 Higher proportions of pupils achieve grades A*-C in the individual sciences (biological science, chemistry and physics) than in any other subject. The majority of pupils taking these subjects attend selective schools (often in the independent sector). Of the compulsory subjects, pupils tend to perform better in English than in mathematics or science. The low figure for the single award science course, reflects the fact that pupils on this course tend to be struggling more generally at school and may have special educational needs.

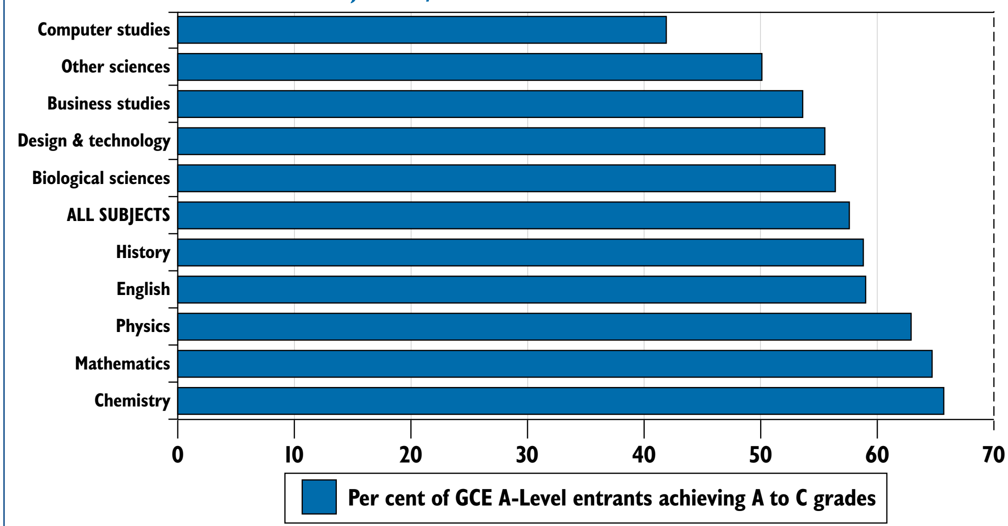
Figure 2.4: Pupils' achievements in selected GCSE examinations, 1999/00



Source: DfES (2001) Statistics of Education: Public Examinations GCSE/GNVQ and GCE/AGNVQ in England.

2.18 However, as Figure 2.5 shows, at A-level the subjects with the highest proportions of pupils with A-C grades are chemistry, mathematics and physics. A cause of this seems to be, in part, that pupils are keen to choose their strongest subjects at A-level, and – to generalise – often only choose mathematics, chemistry and physics if they know they will do well in them. This is consistent with the view of many pupils that these subjects are 'harder' than others – an issue to which the chapter returns later.

Figure 2.5: Pupils' achievements in selected A-level examinations, 1990/00



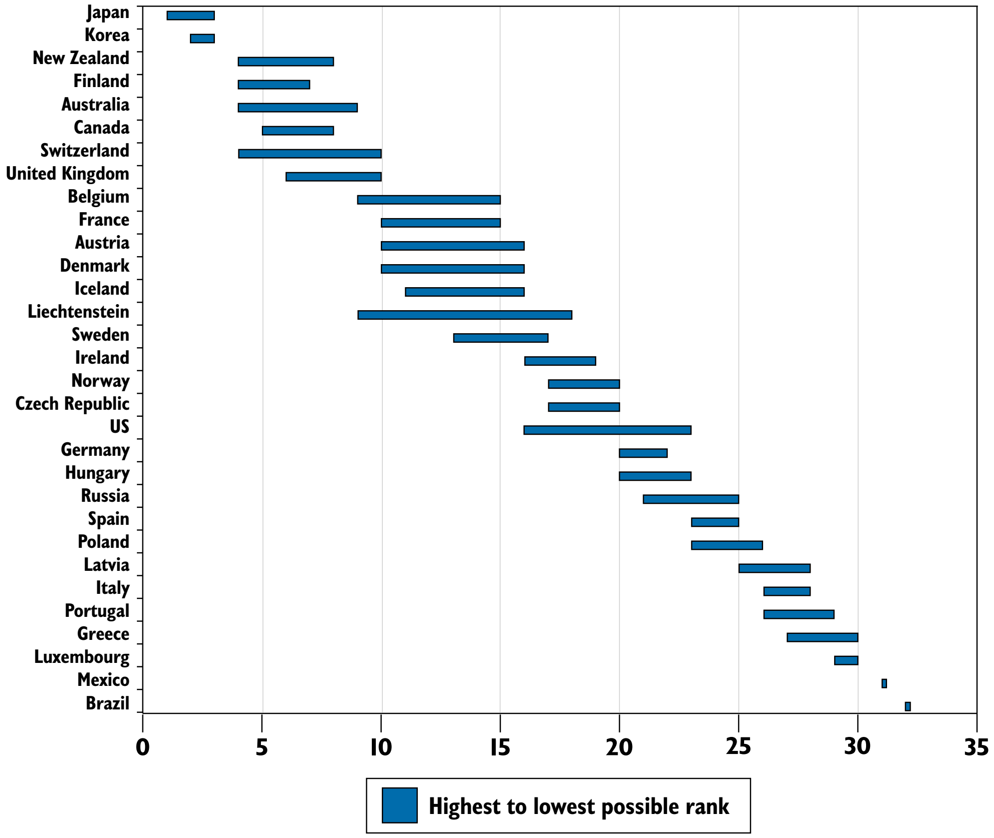
Source: DfES (2001) Statistics of Education: Public Examinations GCSE/GNVQ and GCE/AGNVQ in England.

International comparisons

2.19 The UK compares relatively favourably with other countries when it comes to pupils' achievements in mathematics and science. In the most recent study (the Programme for International Student Assessment (PISA) carried out by the OECD) the UK ranked in the top ten in measures of both mathematical and scientific literacy. The UK was also ranked in the top ten countries in terms of reading ability. Pupils in the UK and US showed a wide range of abilities in the assessments, which the US is addressing through the MSP[41] programme, and the UK through its Key Stage 3 strategy.

2.20 Although these international comparisons paint a reasonably positive picture of achievements by pupils in the UK, they do not measure the motivation they have to study these subjects at higher levels. Furthermore, as shown later in the chapter, there are concerns that many UK pupils' performance is impaired by factors that affect the environment in which mathematics and science are taught. This is particularly relevant given that the spread of pupils' abilities is wider in the UK than in many other countries.[42]

Figure 2.6: Ranks of pupils' mathematical literacy by country

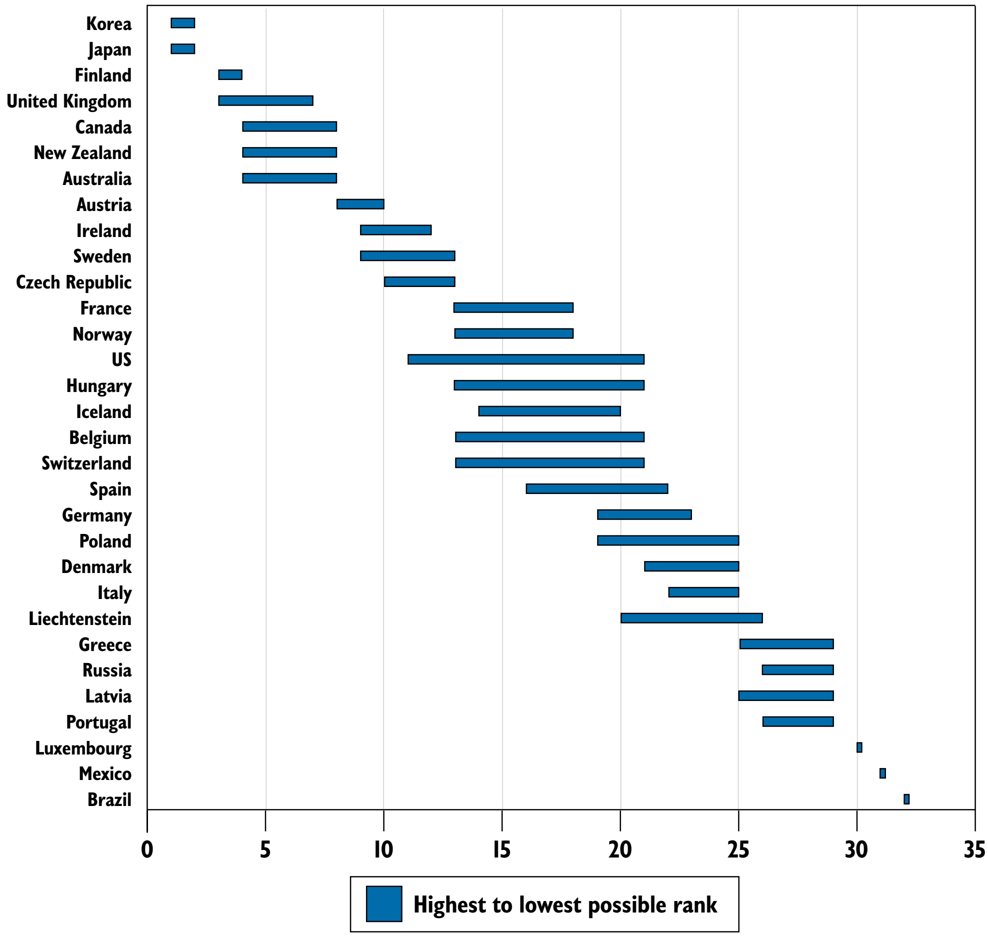


Source: OECD (2002) Programme for International Student Assessment PISA.

[41] Maths and Science Partnership Programme supports schools to work with universities and their community to improve science, technology and mathematics education, and ensure that no child is left behind.

[42] Source: *Knowledge and Skills for Life – First results from PISA 2000,* OECD, 2002.

Figure 2.7: Ranks of pupils' scientific literacy by country



Source: OECD (2002) Programme for International Student Assessment PISA.

Pupils' subject preferences

2.21 The earliest opportunity to judge accurately the enthusiasm and motivation that pupils have for SET[43] subjects is when they choose their AS- and A-level subjects (or equivalents). Until that point the study of mathematics, D&T and elements of the three main sciences is compulsory for the vast majority of pupils.[44] Examining the overall number of pupils studying mathematics, science, D&T and ICT courses at A-level shows that there has been a 4 per cent increase in the number of pupils taking technical or scientific A-levels between 1991/92 and 1999/2000. This upward trend reflects, in part, the growing number of pupils taking A-levels during this period. (There has also been a growing proportion of pupils receiving grades A–C in recent years.)

2.22 However, the trend in overall numbers disguises trends in the choice of individual subjects, which are important in the context of the increasing demand for people with high-level mathematical, scientific and technical skills.

[43] Science, engineering and technology (including mathematics).

[44] Pupils can be 'disapplied' from certain subjects (excused from studying) such as D&T and science in order to spend more time on other subjects.

2.23 Table 2.1 illustrates that in recent years the number of pupils taking mathematics and the physical sciences of chemistry and physics has fallen. The decline has been most marked in physics, where in the period 1991/02 to 1999/00, numbers taking A-levels fell by 21.2 per cent. Chemistry numbers fell by 3.1 per cent, and mathematics numbers fell by 8.5 per cent. Against this trend, numbers taking biology have increased by 12.9 per cent. Other science subjects – e.g. psychology – have also risen in popularity in this period, and in the same period entries to all subjects combined increased by 6 per cent.

Table 2.1: Pupils taking selected A-levels, 1991/92 to 1999/00

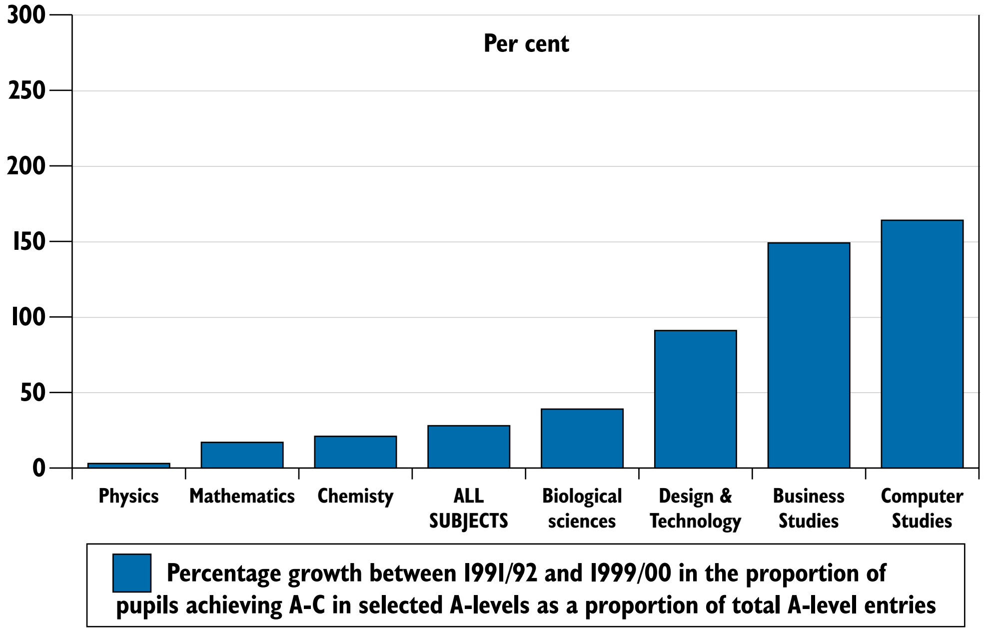
	1991/92	1999/00	Percentage change
Chemistry	37,855	36,696	–3.1
Physics	36,740	28,945	–21.2
Biological sciences	43,408	48,987	12.9
Computer studies	7,747	17,724	128.8
Mathematics	66,395	60,734	–8.5
Design & technology	8,953	13,764	53.7
Business studies	18,466	33,177	79.7
English	79,998	82,910	3.6
ALL SUBJECTS	669,584	709,580	6.0

Source: DfES.

2.24 Falls are also evident at AS-level, with numbers taking AS-levels in physics, chemistry, D&T, biological science and mathematics all falling over the 1990s. However, recent reforms – which aim to make AS-levels a more recognised qualification – should help to reverse this declining trend in AS-levels.

2.25 These trends in the number of pupils taking mathematics and the physical sciences at A-level feed through to smaller increases in the proportion of the whole entry who receive grades A-C in these subjects at A-level (Figure 2.8) and a decline in the proportion choosing to take these subjects at degree level (Table 2.2). Factors relating specifically to undergraduate education that may also be contributing to this fall are discussed in Chapter 3.

Figure 2.8: Percentage growth in proportion of pupils receiving grades A to C at A-level, 1991/2 to 1999/00



Source: DfES (various years) Public Examinations GCSE/GNVQ and GCE/AGNVQ in England

Table 2.2: Entries to selected first degree courses, 1994/95 to 1999/00[45]

Subject	1994/95	1999/00	Percentage change
Biological sciences	12,378	18,450	49.1
Mathematics and physical sciences	17,509	17,270	–1.4
Computer science	8,274	11,210	35.5
Engineering and technology	22,083	20,550	–6.9
All science and engineering subjects	60,244	67,480	12.0
ALL SUBJECTS	237,798	265,270	11.6

Source: UCAS.

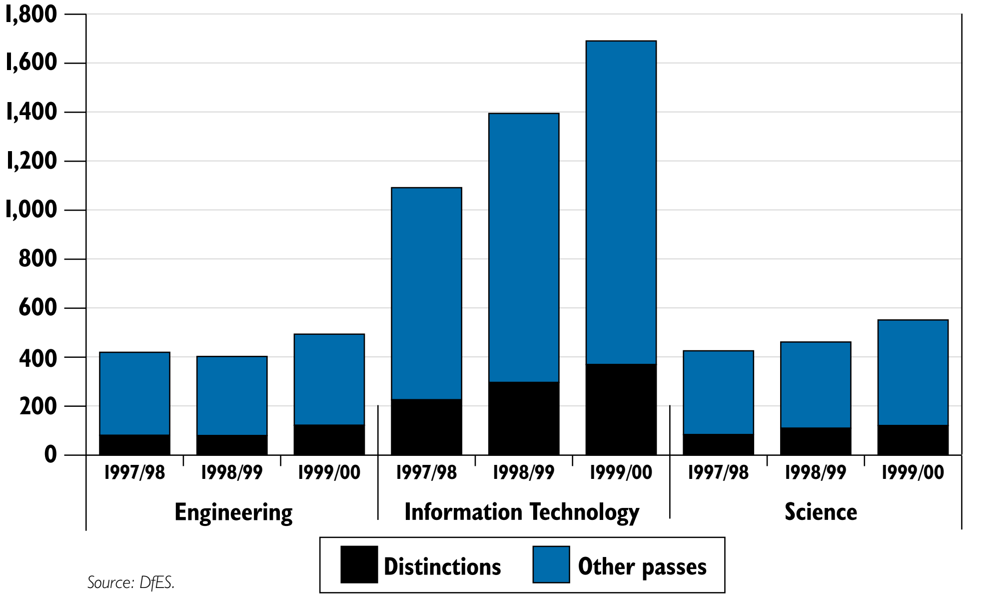
Vocational courses

2.26 The number of pupils studying for vocational qualifications that might lead on to higher education science and engineering courses is relatively small in comparison to those studying A-levels. Figure 2.9 demonstrates that although the numbers taking GNVQs[46] in science, ICT and engineering have increased in the last few years, these numbers are small in comparison, for example, to the nearly 40,000 pupils taking A-levels in chemistry.

[45] Entrants to first degree courses are presented from 1994/95 onwards only, due to data inconsistencies with earlier years (before 1994/95 the current university sector was split into universities and polytechnics).

[46] GVNQs now counted as VCEs.

Figure 2.9: Distinctions and passes in GNVQs, 1997/98 to 1999/00



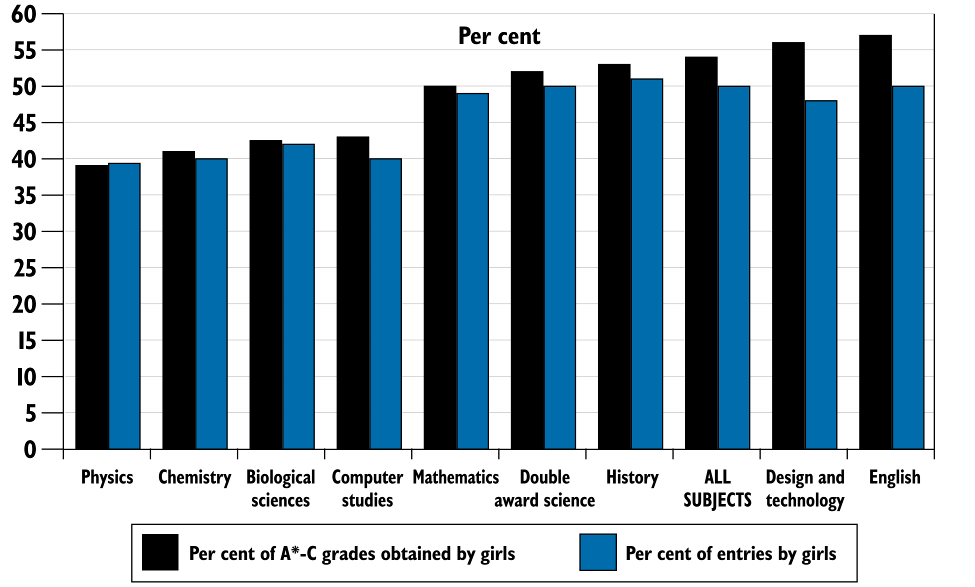
Source: DfES.

2.27 Advanced Modern Apprenticeships also provide a recognised route into higher education. Numbers following this route are small at present because the first cohorts are only now coming through.

Pupil achievements by gender, ethnic group and region

2.28 Before considering the reasons for these trends in the flow of pupils in SET subjects, it is important to consider, within these overall figures, whether there are notable differences between boys and girls, between pupils from different ethnic backgrounds, and by pupils in different regions. Figure 2.10 examines the achievements of girls in selected GCSEs, and shows that in every subject except physics the proportion of A-C grades awarded to girls exceeds the proportion of all those entering the course who are girls. This implies that girls tend to out-perform boys in every subject, with the exception of physics.

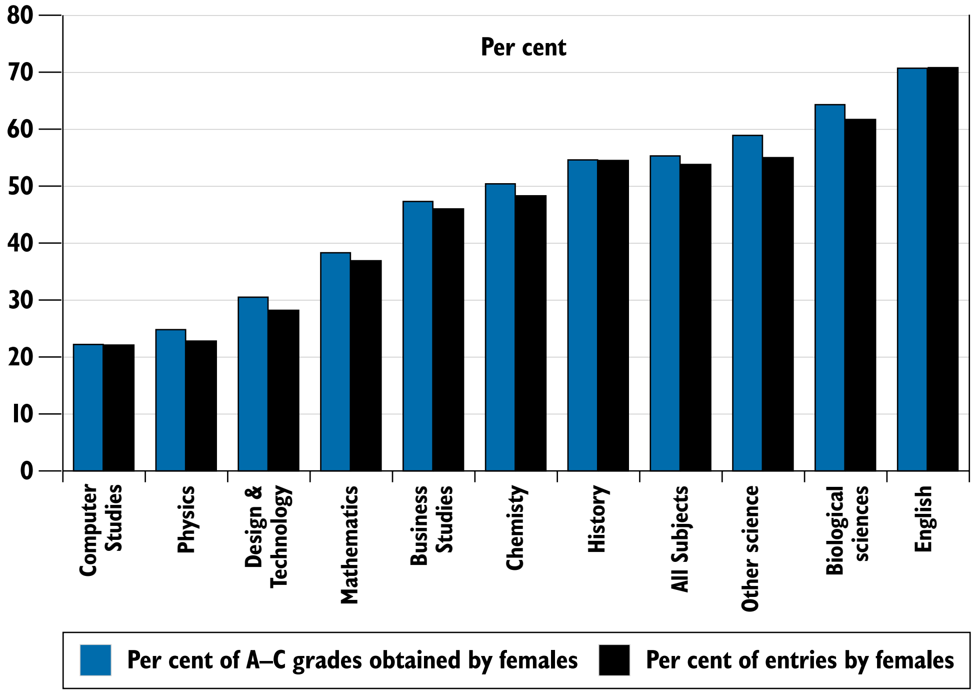
Figure 2.10: Entry and achievement by girls in selected GCSEs, 1999/00



Source: DfES (2001) Statistics of Education: Public Examinations GCSE/GNVQ and GCE/AGNVQ in England.

2.29 Figure 2.11 shows the proportions of those taking science and related subjects at A-level. Although the 'double award' science course has helped to mitigate gender differences between the biological sciences (taken predominantly by girls) and the physical sciences (taken predominantly by boys), these differences are still clear in the data.

Figure 2.11: Entry and achievement by girls in selected A-levels, 1999/00



Source: DfES (2001) Statistics of Education: Public Examinations GCSE/GNVQ and GCE/AGNVQ in England.

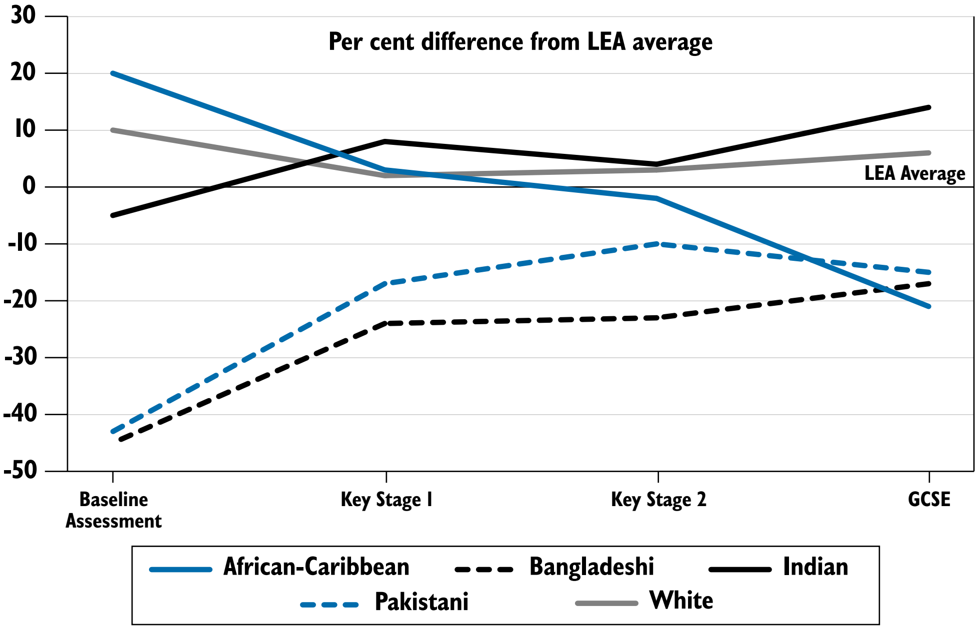
Recommendation 2.1: The participation of women in science and engineering

The Review notes that, despite some recent progress, the proportion of girls studying mathematics and the physical sciences post-16 is still considerably lower than that of boys, which contributes to the under-representation of women in science and engineering more generally. The Review is clear that the under-participation of women in SET is damaging the UK's supply of scientists and engineers, and a number of the recommendations set out in this report should have an important influence on the participation of women in science and engineering.

The Review is aware of a separate study led by Baroness Susan Greenfield, who has been asked by the Government to recommend how to achieve a step change in the effectiveness of measures being used to increase the participation of women in science and engineering. This Review has therefore sought not to duplicate the work of that study but firmly believes that action is required.

2.30 The Review sought to analyse differences in pupil performance between different ethnic groups, but found disturbingly little attention given to this issue. However, whilst the Review was preparing this report the Government announced the creation of a Task Force to examine issues in the achievement of pupils from an African-Caribbean background, which the Review welcomes. This is an area to which the Review urges the Government to give more attention, particularly since the evidence that does exist show considerable disparities between the achievement of pupils from different ethnic groups at various stages of their education.

Figure 2.12: Achievement in mathematics and science by ethnic group of pupil (Birmingham LEA, 1999)



Source: African-Caribbean Representation in Science & Technology (ACRISAT), April 2001.

2.31 Figure 2.12 shows that despite African-Caribbean pupils entering primary school with high levels of numerical and scientific ability and understanding, their achievement declines steadily relative to the average pupil. Pupils from other ethnic minorities (for example, Indian, Pakistani or Bangladeshi students) all tend to improve relative to the average pupil, although there are considerable differences in their initial and final abilities in mathematics and science.

Recommendation 2.2: The participation of ethnic minority groups in science and engineering

The Review is disappointed by the lack of awareness and analysis of differences in achievement and participation in science and engineering between ethnic groups. It is difficult to establish the root causes of these diffierences, based on the evidence available. However, the Review believes that they are significant and therefore recommends that the Government investigate this issue fully in schools, further education and higher education.

2.32 Pupil choices at A-level between regions do not vary greatly although a greater proportion of students in the London region seem to choose mathematics and chemistry than in other regions.

Table 2.3: A-level A–E grades in SET subjects as a percentage of A-E grades in all subjects, by English region

	Biological sciences	Chemistry	Physics	Mathematics	Computer studies	D&T
North East	16	12	9	19	6	4
North West	15	12	8	17	6	3
Yorkshire & Humberside	15	11	8	16	4	5
East Midlands	15	11	8	19	5	5
West Midlands	16	13	9	18	6	4
East of England	14	11	9	20	5	5
London	15	14	9	22	7	4
South East	14	10	9	19	5	4
South West	15	10	9	19	3	5
Total England	15	12	9	19	5	4

Source: DfES; the figures represent the percentage of all A-levels awarded in a region at grades A-E that were awarded in a particular subject. For example, 16 per cent of all A-levels in the NE of England were awarded in the biological sciences.

Summary – The supply of science and engineering skills from schools

There has been some progress in the proportion of those pupils entering SET subjects that achieve grades A*-C at GCSE and A-C at A-level. However, it is worrying that the numbers of pupils choosing to take mathematics and the physical sciences at A-level have fallen so sharply in the early 1990s and are still falling now – resulting in fewer pupils choosing to study these subjects at higher levels.

A shortage of graduates in these disciplines is likely to become increasingly serious since the UK economy – with its large financial services sector, strong science base and increasing focus on high-tech and high-value added manufacturing businesses – is likely to need more mathematics and physical science graduates, not fewer. Furthermore, advances in molecular biology and medical science will in the future depend on those with a quantitative background in physical sciences and mathematics. For these reasons, it is important to consider why more pupils are choosing to take other subjects at A-level and beyond.

An insight into reasons for declining numbers of pupils choosing to pursue mathematics and the physical sciences at higher levels can be gained from studies of pupils' attitudes both to science and to the different sciences. These studies provide evidence that many pupils are dissatisfied with, if not turned off by, the quality of the experience they receive in their school science education[47]. Consequently, the popularity amongst pupils of science, and of physics and chemistry in particular, is low.[48] Subsequent sections consider the underlying factors that cause pupils to turn away from the physical sciences and mathematics.

[47] *Pupils and parents' views of the Role and Value of the Science Curriculum,* Osborne and Collins, BERA Conference, 1999.

[48] *Gender differences in Pupil Attitudes to the National Curriculum Foundation subjects of English, Mathematics, Science and Technology in Key Stage 3 in South Wales,* Hendley, Parkinson, Stables and Tanner, *Educational Studies,* 21(1) (1995) 85-9.

Factors affecting pupils' subject choices

2.33 Four main factors important in improving pupils' achievements in and enthusiasm for particular subjects are:

- teachers, and their style / method of teaching;
- the teaching environment;
- the subject curricula, and subject-related extra-curricular activities; and
- other influences, such as the views that parents, teachers and society more generally have of particular subjects.

2.34 Numerous studies have considered the impact of these factors on pupils' achievements and subsequent choices of further study and eventual careers. However, given the difficulties in isolating any one of them from the others, quantitative evidence on their relative importance is scarce. Their inter-dependence means that tackling any one aspect whilst neglecting others is unlikely to deliver a strong overall improvement. This chapter continues by taking each factor in turn, and examines:

- their role in enthusing students to study science, mathematics, engineering, D&T and ICT;
- the extent to which they could be contributing to the declining popularity of mathematics and the physical sciences; and
- what further measures are necessary in order to secure a strong future supply of science and engineering skills.

Teachers

2.35 Teachers can and do make a huge difference to their pupils' enthusiasm for a subject, as well as directly influencing their pupils' achievements in it. Teachers' subject knowledge and teaching style are vital factors, but it is often their enthusiasm that captures pupil's interest and motivates them to study a subject.

2.36 The Review found considerable differences between the teacher-related issues in primary schools and those in secondary schools and further education establishments. This chapter therefore considers primary and secondary school teachers separately.

Primary school teachers

2.37 Teachers in primary schools generally teach an almost full range of subjects to their class, in order to build as strong as possible a relationship with the pupils. The subject knowledge that teachers require to teach science, mathematics, ICT and D&T in primary schools does not require primary school teachers to have an academic background in them. However, to teach science well, primary school teachers must be able to explain potentially complex scientific principles in an interesting and simple way to pupils, and relate these principles to contemporary issues and the experiences of their pupils. Given that very few teachers have a degree in a science or engineering related subject, it is important for teachers to have access to initial and ongoing science-related continuing professional development (CPD).

2.38 There is considerable concern that primary school teachers are sometimes unable to stretch their pupils adequately in science and mathematics – and that, in particular, there are long-standing weaknesses in the physical processes strand of science. The most recent OFSTED report on primary science found that:

> *"Teachers' knowledge of National Curriculum science has improved considerably over recent years. However, as pupils reach the higher levels of attainment many teachers are working at the limits of their own knowledge and understanding, particularly in physical science. In order to address this, and so support the continuing trend of rising standards, particularly in physical processes and the newly formulated Scientific Enquiry, teachers' knowledge of science needs to be further improved."*

2.39 This is supported by work carried out for the Council for Science and Technology,[49] which revealed that primary school teachers had less confidence teaching the physical processes and experimental investigation strands of science, than they had teaching the life and living processes strand. This weakness in the teaching of physical processes in primary schools is a serious concern given the declining numbers of pupils taking physics and chemistry at A-level and beyond.

2.40 Furthermore, given this shortfall in teachers' confidence and understanding of the physical sciences, it is worrying that few teachers develop their subject knowledge through CPD,[50] and that little personal reward follows if they do so. Primary school teachers' training is mostly taken up with school administration issues and national initiatives on numeracy and literacy and ICT. Difficulty in identifying suitable courses, as well as time and money, were also cited as reasons for low participation in subject-related CPD. The idea of a National Centre for Excellence in Science Teaching (discussed in more detail in the section relating to secondary schools and further education) should help in this regard.

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[49] *Science Teachers: a report on supporting and developing the profession of science teaching in primary and secondary schools, CST,* February 2000.

[50] *A study into the professional views and needs of science teachers in primary and secondary schools in England,* CST, January 2000.

Recommendation 2.3: Primary school teachers

The Review recommends that the Government ensure that primary school teachers receive greater subject-specific training (in particular, in relation to the physical sciences and mathematics) both in their initial training and through Continuing Professional Development to enable primary teachers to build on the progress they have made so far. Furthermore, the Government should review, in three years' time, the progress made in improving primary school teachers' confidence in teaching all areas of the mathematics and science curricula, and take further action as necessary.

Teachers in secondary schools and further education colleges

2.41 Many secondary schools and further education colleges have considerable difficulty in recruiting and retaining science and mathematics teachers (the problems also apply to a limited number of other subjects, such as modern foreign languages). A common characteristic of the subjects is the extent to which there is high demand from other employers for the skills – for example, high levels of numeracy, and strong analytical and problem-solving skills – that graduate teachers in these subjects are likely to possess.

2.42 The most recent OFSTED subject teaching reports revealed that:

- *"[In mathematics] there are insufficient teachers to match the demands of the curriculum in one school in eight, a situation that has deteriorated from the previous year."*
- *"[In science] the shortage of physical science teachers is having a negative impact on the quality of teaching and management in a substantial number of departments."*
- *"[In Design and Technology] the shortage of specialist teachers, particularly for food technology and for systems and control, is now acute, especially in some parts of the country, and is depressing pupils' attainment."*

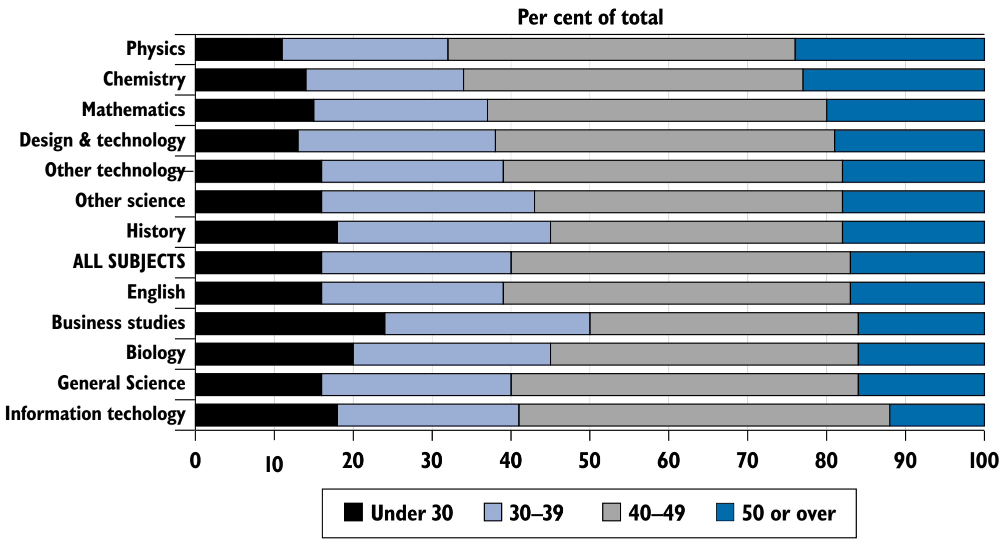
2.43 Analysis of data on vacancies as a percentage of teachers in post[51] confirms that shortages in teachers of mathematics (in particular) and science, D&T and ICT are more acute than for many other subjects. A survey by Smithers and Robinson (2000) found that head teachers had most difficulty filling posts in mathematics, physics and chemistry (and a limited number of other subjects). These shortages apply across the country but are particularly acute in London, where the high cost of living and perceptions of classes being more difficult to teach are seen as particularly off-putting factors. The Government only sets targets for science teachers, overall, and not for teachers of biology, chemistry and physics. As a result, the published shortages mask even more acute shortages in the physical sciences.[52] There is a growing trend of using biological science graduates, who are in more plentiful supply, to teach physics and chemistry.

[51] Source: DfES.

[52] A survey carried out by Smithers and Robinson (DfEE Research, University of Liverpool), in September 2000 indicated that school heads were experiencing particular difficulties in recruiting teachers capable of teaching physics and chemistry at higher levels.

2.44 International comparisons suggest that while other countries experience shortages of science and mathematics teachers the position in the UK is worse. Furthermore, these teacher shortages in mathematics, physics, chemistry and D&T could well worsen over time, since as shown in Figure 2.13 teachers whose main qualification is in these subjects tend to be older than their counterparts in other subjects.

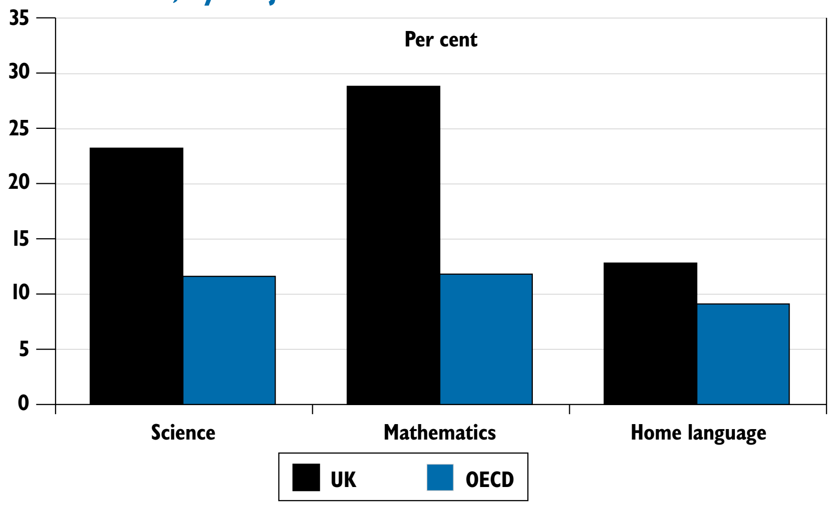
Figure 2.13: Teacher demographics by discipline



Source: 1996/97 Secondary Schools Curriculum and Staffing Survey.

2.45 Teachers shortages can adversely affect pupil performance. Figure 2.14 shows the proportion of head teachers who believe that a shortage or inadequacy of teachers is hindering the learning of pupils in different subjects either 'a lot' or 'some'.

Figure 2.14: Proportion of schools in which teacher shortages/ inadequacy are adversely affecting pupils' performance, 'a lot' or 'some', by subject



Source: OECD (2002) Programme for International Student Assessment PISA.

Teacher recruitment and retention

2.46 Teachers working in maintained schools in England must hold Qualified Teacher Status (QTS), which is usually obtained through completing Initial Teacher Training (ITT). There are three main routes for achieving QTS: as part of an undergraduate degree (mostly used for primary school teachers); through a postgraduate training course, often combined with study for a Postgraduate Certificate in Education (PGCE); or – for people over the age of 24 – via employment in schools on the Graduate Teacher Programme or (for those without a first degree but with two years' study in higher education) the Registered Teacher Programme. About 200 people enter science and mathematics teaching each year through either the Registered or Graduate Teacher Programme compared to over 4,000 entering through ITT.

2.47 Most postgraduate trainee teachers in England on an eligible ITT course will receive a £6,000 training bursary. An additional £4,000 is available for eligible postgraduates who go on to teach in shortage subjects in England,[53] and some further training awards are available to secondary school teacher trainees in shortage subjects based on financial need.[54]

2.48 These incentives have had an effect but, as Table 2.4 illustrates, there are still considerable difficulties in recruiting maths and science graduates to teaching. These figures, relating to those entering initial teacher training in 2001, are more encouraging than for previous years, and reflect the new measures (referred to in the previous paragraph) introduced to try and address teacher recruitment difficulties in shortage subjects. Nevertheless, significant numbers of mathematics and, to a lesser extent, science teacher places remain unfilled – a situation that has remained unchanged since the early 1990s.

Table 2.4: Targets and actual recruitment for Initial Teacher Training in England, 2001

Subject	Actual recruitment	Target	Percentage of target met
Mathematics	1,546	1,940	80
Modern languages	1,692	2,050	83
Science	2,591	2,810	92
History	922	900	102
English & drama	2,229	2,160	103

Sources: Recruitment – TTA ITT trainee number census, 2001; Targets – DfES.

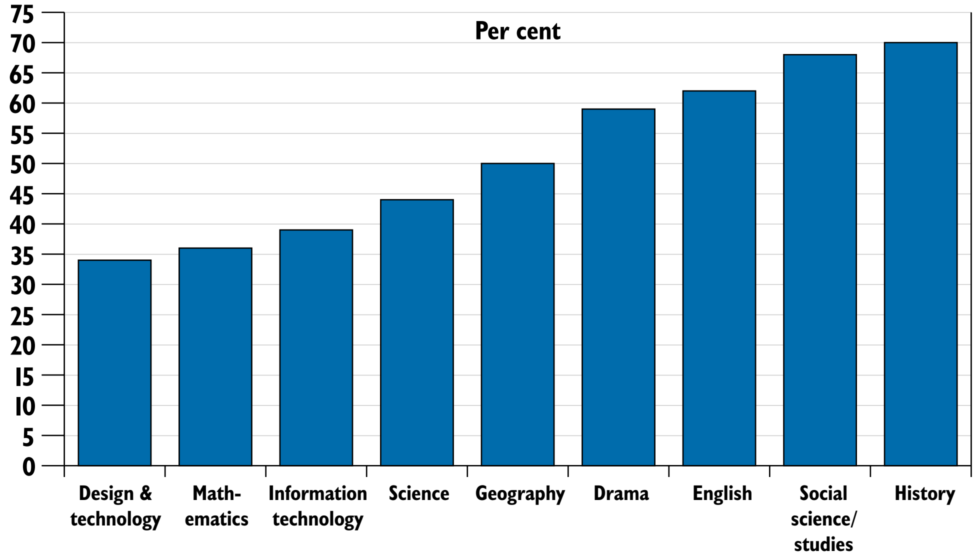
[53] This additional £4,000 is available for eligible postgraduates teaching mathematics, science, English, modern languages, design and technology or ICT in England. It can be claimed by those successfully completing induction within five years of the start of the first academic year after gaining Qualified Teacher Status and, within 12 months of completing induction, working in a relevant teaching post in the maintained sector.

[54] These awards are for secondary school teacher trainees on undergraduate and postgraduate ITT courses studying one of the following subjects: mathematics, science, modern foreign languages, design and technology, information and communications technology, religious education, music or geography. Maximum payments in any one year are £5,000 (£7,500 for those aged 25 or over). These maximum amounts are only awarded in exceptional circumstances and there is no automatic entitlement to any level of payment.

2.49 It is also important to consider the small but growing number of mature entrants to teaching and returners to the teaching profession. Given the relatively small number of graduates in mathematics and the physical sciences, late entrants to the teaching profession in these subjects are likely to become increasingly important. In this context, the Review supports the Government's "Welcome back bonus" for teachers returning to the profession. Teachers returning in a shortage subject such as mathematics receive £1,000 shortly after returning, plus £3,000 around a year later.

2.50 Alongside shortfalls in numbers, the data also suggest clear differences in the pool of recruits attracted to teaching different subjects. Figure 2.15 presents data relating to the proportion of recruits to Initial Teacher Training with a degree class of 2:1 or better. Whereas nearly 70 per cent of applicants to teach history achieve this standard, the proportion of maths and D&T applicants with a similar level of qualification is roughly half this. There is no necessary link between degree class and ability as a teacher (there are, for example, highly-qualified scientists and mathematicians who have poor communication skills and who would find it difficult to teach their subject well).[55] However, this chart clearly suggests that teaching is not attracting the same pool of talent in mathematics, D&T, science and ICT as it is in many other subjects.

Figure 2.15: Proportion of entrants to Initial Teacher Training with a 2:1 or better in their first degree, 2000



Source: Graduate Teacher Training Registry.

Teacher retention

2.51 Retention of qualified teachers is just as important as recruitment onto ITT courses. Evidence to the House of Lords Select Committee on Science and Technology – supplied as part of their review into science in schools – revealed that 30-40 per cent of newly qualified science teachers leave the profession within five years of joining, which is believed to be higher than other subjects

[55] It may be, however, that those teachers with a third class degree or lower, may benefit from more subject-specific Continuing Professional Development (CPD) than those receiving, for example, a first class degree.

(although data are not available to support this comparison directly). Reasons given by teachers for leaving, and the main factors that would need to be addressed to tempt them back, are: heavy workloads; poor pupil behaviour; low salaries; and what they view as an excessive number of government initiatives.

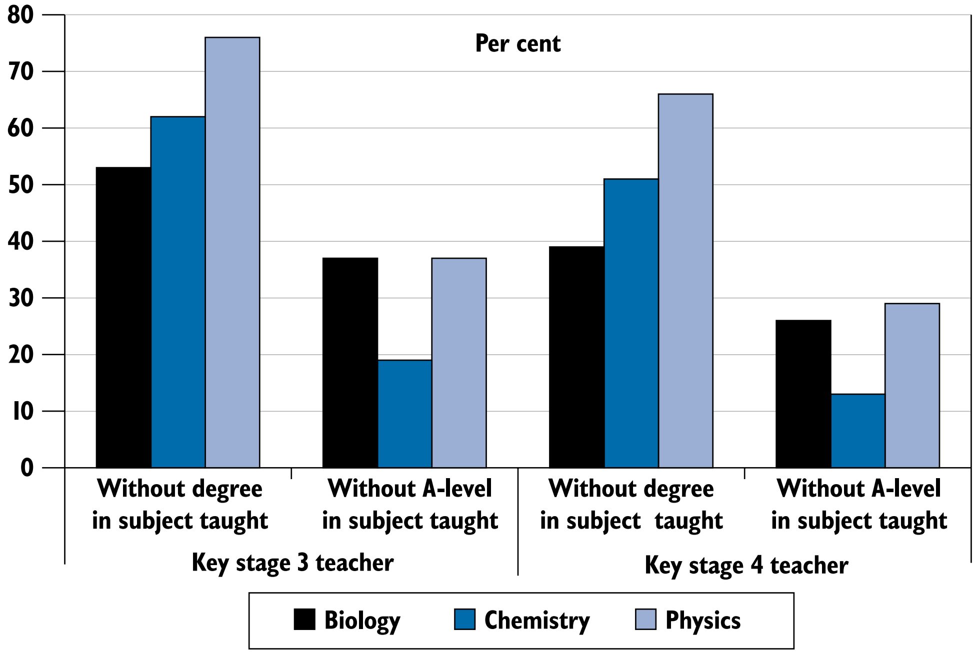
Subject specialisation in science teaching

2.52 The Review's consultation revealed widespread concern over the effect of teachers teaching areas of science that were not covered in their degree programme (for example, a biological science graduate teaching physics). In particular there is concern that the dwindling numbers of physical science graduates are feeding through into a falling number of teachers with a background in the physical sciences.

2.53 The introduction of the double award science course at GCSE has increased the phenomenon of science teachers teaching outside their area of expertise, since schools often prefer this to losing continuity in the classroom.[56] Recent work by the Council for Science and Technology shows the extent of this problem.

2.54 Since most science degrees tend to be in a single science (e.g. chemistry), and yet graduate teachers are often expected to teach across the science, it is expected that around two-thirds will not have a degree in the subject taught. However, Figure 2.16 shows over 75 per cent of the teachers teaching physics at Key Stage 3 did not study for a physics-oriented degree. This is substantially higher than the equivalent proportions for those teaching

Figure 2.16: Proportion of teachers of physics, chemistry and biology without qualifications in the subject



Source: Council for Science and Technology.

[56] Concern has also been expressed in D&T regarding a perceived inadequacy in the subject-content training element of ITT.

chemistry or biology. Furthermore, nearly 40 per cent of the teachers teaching physics at Key Stage 3 do not have an A-level in physics. This is similar to biology, but roughly double that for chemistry (reflecting the fact that, historically, many students studying physics or biology at A-level would also have taken chemistry – viewing it as a 'neighbouring' science, as well as a qualification which is a necessary requirement for entry to many biological science and medicine degree courses).

2.55 At Key Stage 4, there is slightly more subject specialisation, although nearly 30 per cent of those teaching physics do not have an A-level in the subject.

2.56 It is important to stress that science teachers may well be able to teach science outside their area of scientific expertise. Indeed, many currently do so and perform well. Such arrangements are essential given difficulties in the supply of teachers of the physical sciences. However, teachers are most likely to have an inspirational effect on pupils when teaching interests them most. The shortage of teachers with a background in physics and chemistry is likely to result in a vicious circle of fewer students choosing to pursue these subjects at a higher level and in turn, fewer teachers being available to inspire the next generation of students.

2.57 However, if science teachers are expected to teach outside their area of expertise, the importance of comprehensive cross-subject training as part of the ITT Programme – and the availability and uptake of subject-specific Continuing Professional Development – cannot be overestimated.

2.58 The Review consulted newly-qualified science teachers on the amount of support they were given during their ITT programme to teach outside their specialist area. The overwhelming view was that the amount of training and support provided was insufficient to improve significantly their confidence in teaching science outside the scope of their degree (particularly at Key Stage 4). Given the dominance of biological science entrants to ITT, the subject-specific training elements of ITT must be addressed if schools are to generate students wanting to study the physical science at university.[57]

Recommendation 2.4: Secondary school science teachers' training

The Review recommends that in order to enhance the quality of teaching across the sciences – and in the physical sciences in particular – the Government should act to improve significantly the subject-specific training and support given to science trainee teachers on initial teacher training and other teacher entry programmes. Furthermore, the Government should review, in three years' time, the progress made in improving secondary school teachers' confidence in teaching all areas of the science curriculum, and take further action as necessary.

The Review also recommends that in recruiting science graduates the Government should pay more attention to their areas of specialism (*e.g.* physics, chemistry or biology) to ensure an adequate supply of teachers able to teach the individual sciences (particularly physics and chemistry) at higher levels.

[57] Independent schools often avoid the above problems through keeping the individual sciences separate, even if their students take the double award science.

Improving the supply of science, mathematics, ICT and D&T teachers

2.59 The Review acknowledges that views of managing the delivery of teaching are being updated. In a speech to the Social Market Foundation last November, the Secretary of State for Education and Skills initiated a debate on the structure of the teaching profession – covering issues such as: the role of adults in the classroom and beyond; what teachers should and should not do; and the use of ICT. Through this debate the way in which the demand for fully qualified teachers is assessed is likely to evolve.

2.60 Nevertheless surveys of those entering teaching – or those who decided against entering teaching – identify a number of reasons that act to deter students from teaching. As shown in the table below, by far the main factor in deterring potential physics teachers is pay, with pupil behaviour a clear second. Amongst those not in teacher training, the intellectual challenge, lack of career prospects and the public perception of teachers also rank highly, although all are dwarfed by the issue of pay.

Table 2.5: Deterrents to teaching

	Trainee Teachers		Other students	
Issue	**rank**	**per cent**	**rank**	**per cent**
Pay	1	22.4	1	36.8
Pupil behaviour	2	13.7	2	22.8
Intellectually inferior	13	1.1	3	8.8
Public perception / status	=4	10.9	=4	7.0
Lack of career prospects	11	1.6	=4	7.0
Government interference	6	4.4	6	3.5
Stress / hard work	3	11.5	=7	1.8
Training problems (e.g. money)	=4	10.9	=7	1.8
Lack of confidence in teaching	10	10.2	=7	1.8

Source: Supply, recruitment and retention of physics teachers, Constable, Howson, Bolden and Spindler, TTA.

2.61 If the Government is seriously to address the recruitment and retention of teachers, action is required on a number of fronts. However, the review believes that this is most critical in two particular areas, namely teachers' remuneration and the need for Continuing Professional Development (CPD), which are considered in more detail below.

Teachers' remuneration

2.62 From 1 September 2002 teachers in maintained secondary schools will be paid on a new salary scale, on which most teachers will progress from £17,268 to £25,746 within six years, after which they will apply to pass a performance threshold (if successful, moving to a new pay scale of £27,894 to £32,250) or move to a different pay scale (for example, by becoming a head of department, or becoming an Advanced Skills Teacher).[58] One of five management allowances ranging in value from £1,593 to £10,275 may be awarded in addition to pay scale points to heads of department and other teachers with management responsibilities. The most senior teachers become assistant or deputy head teacher or head teachers on the leadership pay spine with a maximum of over £85,000.

2.63 Although in principle schools have considerable freedom over the pay of their teachers, few tend to vary significantly from the traditional pay scales and progression routes. Schools are also able to use recruitment and retention allowances – of between roughly £1,000 and £6,000 – to attract and keep key members of staff. At present, around 3 per cent of teachers receive such an allowance (rising to around 12 per cent for teachers in London). There are further graded allowances for staff living in Inner, Outer, and 'Fringe' London (of around £3,000, £2,000 and £1,000 respectively), reflecting the higher costs of living in and around London.

2.64 The Government has also gone further in seeking to target additional remuneration on teachers of shortage subjects. Specifically, trainee teachers in shortage subjects (which include mathematics and science) are offered golden hellos, worth £4,000. The Government has announced that teachers in shortage subjects will also benefit from having their student loans written off over a period of time. This would further increase the effective salaries of science, mathematics, ICT and D&T teachers, potentially by up to around £1,500 per year for the first ten years. The box below explains how the scheme for paying off student loans would work.

Writing off student loans

The Government is currently legislating to enable teachers in shortage subjects to have their student loans written off over a period of up to 10 years.[59] The shortage subjects for schools and further education establishments include mathematics, science, design and technology, ICT, engineering and construction. This would potentially be worth £11,715 spread over 10 years to a student with the maximum student loan who studied outside London, or 33 per cent more (around £1,500 per year) if the student had been on a four year degree, in a physical science for example. This inducement will have less impact on those students who did not take out loans or who have worked during their vacations to support themselves through university, and as a result have little debt. (However, training bursaries, golden hellos and other incentives will, of course, influence their decision making).

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[58] The Advanced Skills Teacher (AST) grade was introduced in 1998 and offers a new career route with an enhanced salary scale (up to £46,000 a year) for excellent teachers who do not wish to take up management posts. ASTs continue to work mainly as classroom teachers but also spend time working with teachers in their own and other schools to raise teaching and learning standards. To qualify for an AST post teachers have to pass a rigorous assessment process. Schools receive a grant jointly funded by the DfES and the Local Education Authority to cover the additional cost of creating an AST post.

[59] The loans can either be general subsistence loans or mortgage loans, this box focuses on the former.

2.65 Finally, the Government has introduced two other measures to try improve the career progression of the 'best' teachers, or those considered to have the most potential: the Fast Track[60] and the Advanced Skills Teachers Scheme. To the extent that higher rates of training bursary, golden hellos and the writing off of student loans succeed in attracting more and better qualified science and engineering graduates to teaching, their career prospects and incentives can be improved through fast-tracking and other performance incentives. The Review encourages the Government to evaluate the impact of these recent and varied incentives to enter and remain in teaching, including the student loan write off once that policy becomes operational in autumn 2002.

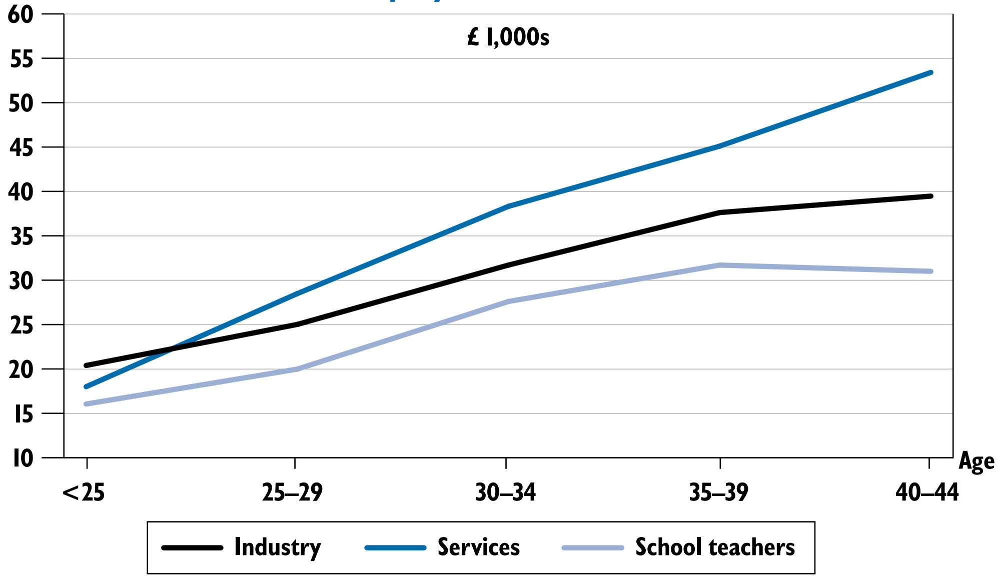
The effect of remuneration on teacher recruitment

2.66 The chapter has set out the structure of teachers' pay and the additional measures the Government has introduced to try to turn teaching into a 'career for the ambitious' and to address the particular shortages in subjects such as mathematics and science. These measures have begun to have an effect, with increasing numbers choosing to enrol on ITT courses. However, recruitment targets in mathematics and science are still being missed and the serious shortages in teachers of these subjects persist.

2.67 Figure 2.17 shows that physics teachers earn considerably less than they could in other sectors of employment. Based on a survey of its members, the Institute of Physics (IoP) estimates that, over their working lives, physics graduates choosing to teach would forego an average of £350,000 compared to their likely earnings in other jobs. Figure 1.7 in Chapter 1 also sets out the fact that physics (and mathematics, chemistry, ICT and engineering) graduates could expect to earn a significant premium above the average salary, of between 15 and 20 per cent. This helps to explain why the salary available as a teacher may appear less attractive to graduates of these disciplines than of others.

[60] Now in its second year of recruitment, the Fast Track Programme currently takes in around 100 applicants a year, with growth planned to take in several hundred per year in the near future. It aims to identify and develop individuals with the greatest leadership potential and is aimed at those who will become part of the senior management team of a school or an advanced skills teacher. In the first year, only new entrants to the teaching profession were eligible, but it has now been extended so that existing teachers can also apply. The long term aim is for 5% of the teaching profession to be on (or to have been through) the Fast Track scheme. Those on the Fast Track join the pay scale around £1,500 higher than normal, and receive an additional £5,000 bursary if they are new entrants to teaching. They progress up the pay scale at twice the speed – meaning they reach around £26,000 within three years (excluding additional allowances).

Figure 2.17: Median salaries of male physics graduates in different sectors of employment, 2001[61]



Source: Institute of Physics.

2.68 The issues surrounding the pay of science and mathematics teachers (and of other teachers whose skills are in very high demand elsewhere in the economy) also, of course, exist in many other countries. The box below sets out one innovative scheme in the US that is being used to address shortages in the supply of scientists and engineers.

North Carolina – Teacher shortage initiative

In North Carolina, teachers of mathematics, science or special education at middle and high schools with more than 80 per cent of pupils eligible for free or reduced school meals or with more than half of all pupils achieving below certain levels in mathematics and science, are eligible for annual bonuses of $1,800.

These additional pay incentives form part of a wider package aimed at improving the science and mathematics performance of underachieving pupils.

2.69 This analysis leads to the following recommendation, which the Review belives is important for the future supply of scientists and engineers in the UK.

[61] Data for women have been removed since the data are relatively volatile.

Recommendation 2.5: Teachers' remuneration

The Review recommends that, to solve the serious shortages in mathematics, science, ICT and D&T teachers, more must be done to address the pay and other incentives offered to teachers in these subjects. The Government, schools and colleges must compete for graduates in these disciplines in the labour market by, amongst other measures, providing more attractive remuneration for teachers in these subjects, to better enable schools to attract graduates who can earn higher salaries in other sectors of the economy. This will require head teachers and governing bodies to pay teachers in shortage subjects more than other teachers, which is the more economically efficient response to shortages in supply.

The Review therefore recommends that the Government tackle such recruitment and retention problems through increasing the remuneration offered to teachers of these shortage subjects – and also that head teachers and governing bodies use all the pay flexibility at their disposal. Furthermore, the Review recommends that this additional remuneration be linked – wherever possible – to teachers' take-up of CPD activities and opportunities, thereby rewarding those teachers who make particular efforts to improve further their subject knowledge and teaching style.

Continuing Professional Development

2.70 CPD is vital for all teachers, but especially for teachers in science and technology, who must stay abreast of technical and scientific progress in order to capture pupils' interest through engaging them in contemporary scientific issues. Teachers with knowledge of the latest developments in the sciences are better able to interest science and engineering students in these subjects and enthuse them to study the subject at a higher level. CPD is also an important element of the professional package that teachers should expect from their employer – in particular, giving them the ability to stay in touch with their specialist subjects. CPD is therefore important as a recruitment and retention mechanism and as a means of improving teaching quality.

2.71 When questioned by the House of Lord Committee on Science and Technology, Estelle Morris (in her then role as Minister for School Standards) agreed with the argument that science teachers require considerable CPD to stay at the forefront of science and technological progress:

> *"I can quite see that scientists might make the case that their content knowledge changes and needs updating more than content knowledge elsewhere. I do not think I can argue with that."*

2.72 As with their counterparts in primary schools, the Council for Science and Technology revealed that the secondary school science teachers at Key Stage 3 and Key Stage 4 had less confidence in teaching the physics elements than the biology and chemistry elements. Teachers' levels of confidence were found to be strongly correlated to the highest level of qualification that the teacher had in the subject. Teachers' confidence and understanding are important influences on the achievements of their pupils. These lower levels of confidence are therefore important factors in the decline in numbers of students choosing to study the physical sciences at higher levels. The House of Lords Committee[62] also concluded that teachers often lacked the confidence and knowledge to conduct experiments safely – an issue that needs to be addressed through CPD.

2.73 Public funding up to £500 is available for teachers in their fourth and fifth years of teaching to spend on a wide range of CPD activities. Schools can also pay for teachers to undertake voluntary CPD at weekends or during school holidays, although take-up of these opportunities is low at present. Teachers also get receive five days of INSET (In-Service Education and Training) during their conditioned hours of work. However, the House of Lords Select Committee on Science and Technology noted in their report on science in schools that, in their view, the majority of teachers are rewarded only very infrequently for undertaking CPD – in contrast with how CPD is viewed and used in a number of other countries. For example, in Canada science teachers can receive additional pay for engaging in project work alongside a local university.

2.74 In this context, the Review welcomes the Government's strategy to boost CPD, as set out in *Learning and Teaching: a strategy for professional development* launched on 1 March 2001. This puts increased opportunities for professional development at the heart of school improvement.

Recommendation 2.6: Secondary school teachers' Continuing Professional Development (CPD)

The Review recommends that the Government improve science teachers' access to, and take up of, subject related CPD, which will benefit their teaching and also act to improve retention. In particular, the Review recommends that all science teachers be incentivised to undertake CPD, and that the range of recognised CPD activities be as broad as possible. For example, it should include the possibility of participating in scientific research carried out in industry and universities. The Review welcomes the Government's commitment to a National Centre for Excellence in Science Teaching. It also notes the interest of the Wellcome Trust and hopes that the Government and the Trust can form the sort of partnership that has been so fruitful in other areas of science policy.

[62] House of Lords Select Committee on Science and Technology, First Report, 14 March 2001.

The teaching environment

2.75 Pupils' learning experiences are influenced not just by the teacher but also by the environment in which subjects are taught. There are a number of factors that influence the quality of the teaching environment. The consultation process identified three factors as particularly important for science and D&T:

- the quality of the laboratory and associated scientific and technical equipment;
- the support provided by laboratory technicians; and
- the support and guidance that pupils have in carrying out practical work (with particular reference to the adverse effect of high pupil-to-teacher ratios).

School science and D&T laboratories

2.76 Science and D&T laboratories and equipment are vital to pupils' education in these subjects – both in directly educating pupils about areas of science and technology and in interesting them and enthusing them to study these subjects further. However, it is widely considered that the standard of many school laboratories[63] in England has failed to keep up with the pace of scientific and technical progress, and many school laboratories have failed to receive the investment crucial to providing positive experiences for pupils.

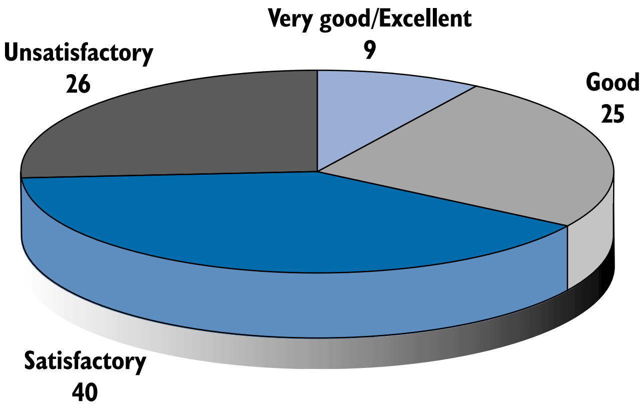
2.77 Recently, increased investment in schools more generally[64] has been coupled with specific investment of £60m over two years (2000/01 and 2001/02) aimed at rebuilding or modernising some laboratories that were in desperate need of improvement. However, although there are good examples of modern and well equipped laboratories, a substantial proportion of school laboratories are not satisfactory environments in which to teach science or design and technology. Nor do they often have suitable IT equipment to enhance the quality of the learning experience.

2.78 Regrettably, a full assessment of the state of school laboratories in England is not available since the data are not collected centrally. However, information gathered from OFSTED inspections suggests that around one-quarter of school science laboratories are 'unsatisfactory' for teaching science, and that only slightly more than a third provide a 'good' or 'very good' environment. This situation is comparable to the state of D&T laboratories, but is significantly worse than the state of accommodation used in nearly all other subjects.

[63] In this section the term 'laboratories' is intended to include scientific and technical equipment in the actual laboratory.

[64] In 1996/97 capital spend on schools (excluding IT) was £683 million. In 2002/03 it is £2.8 billion and in 2003/04, it will be £3.5 billion. These greatly increased levels of funding have allowed the most urgent repairs to be addressed, though not all the backlog is yet eliminated. However, the balance of investment is turning from patch and mend repairs to modernisation and suitability needs, including those of school science and D&T facilities.

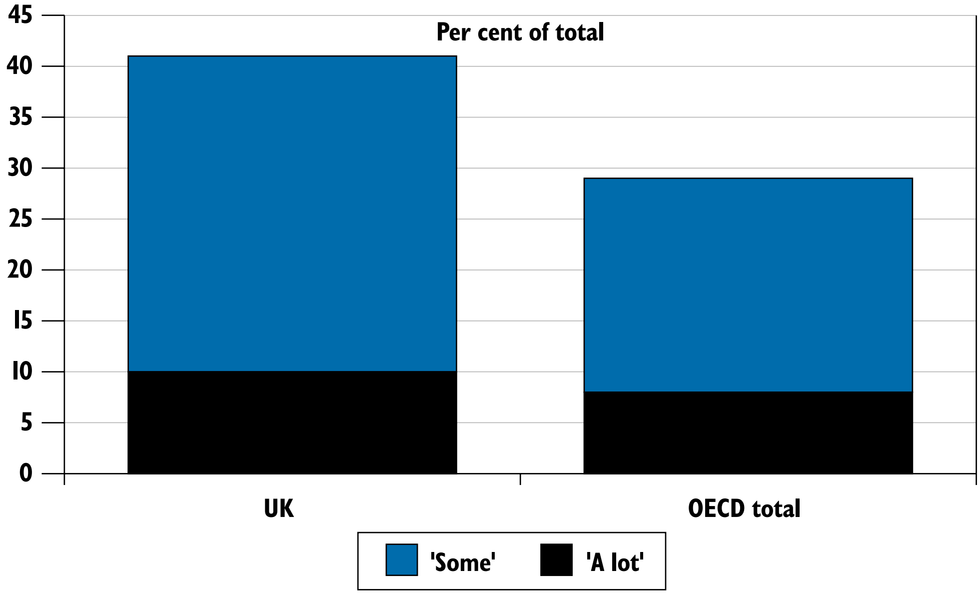
Figure 2.18: Adequacy of school laboratories, 2000/01



Source: OFSTED.

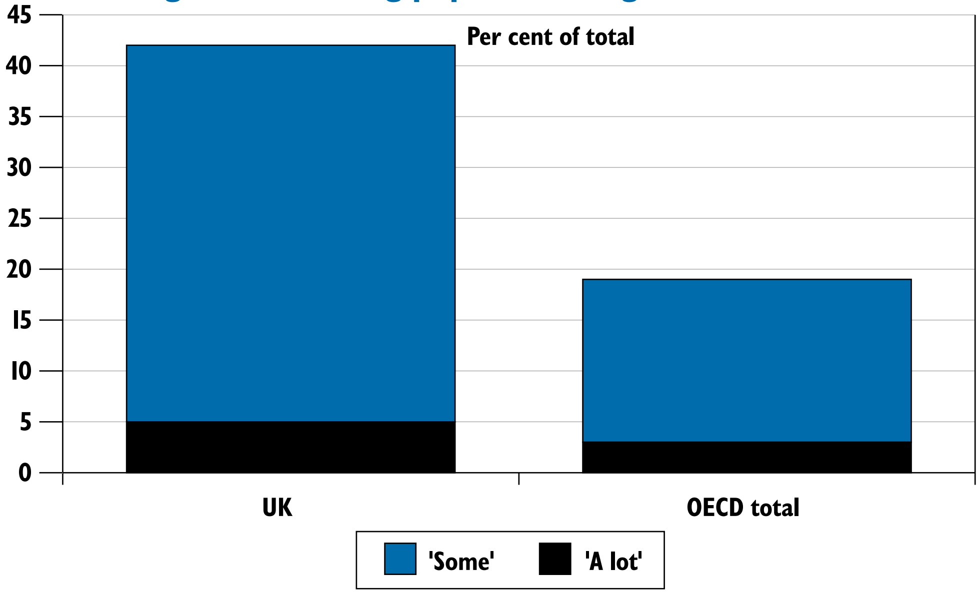
2.79 Information compiled by the OECD also suggests that the learning experiences of pupils in the UK may be hindered by the state of science equipment and buildings relative to other countries (Figures 2.19 and 2.20).

Figure 2.19: Proportion of schools in which inadequate science equipment is hindering pupils' learning



Source: OECD (2002) Programme for International Student Assessment PISA.

Figure 2.20: Proportion of schools in which inadequate buildings are hindering pupils' learning



Source: OECD (2002) Programme for International Student Assessment PISA.

Recommendation 2.7: School laboratories

School science and D&T laboratories are a vital part of pupils' learning experiences in these subjects, and should play an important role in encouraging pupils to study these subjects at higher levels. However, it is clear that for many pupils this is not the case. To address this, the Review recommends that the Government and Local Education Authorities prioritise school science and D&T laboratories, and ensure that investment is made available to bring all such laboratories up to a satisfactory standard (as measured by OFSTED) by 2005. Furthermore, the Review recommends that these laboratories should be brought up to a good or excellent standard (again, as measured by OFSTED) by 2010: a standard which is representative of the world of science and technology today and that will help to inspire and motivate students to study these subjects further. The Government should take all appropriate steps to ensure that these targets are met.

Science and D&T technicians

2.80 Science and D&T technicians perform vital roles in the department(s) in which they work – enabling the teachers to teach and the pupils to learn. Common areas for which technicians take responsibility include:

- preparing equipment and laboratories for practical classes;
- maintaining technical and scientific equipment and laboratories;
- ensuring teachers and students can teach and learn in a safe environment, through considering health and safety issues;
- directly supporting teachers in their practical classes, including assisting pupils to get the most out of experiments; and
- administrative and other functions underpinning the smooth running of the department.

2.81 However, schools find it difficult to attract and retain technicians, due, primarily, to the pay and career structure available to technicians in schools and colleges. Recently, a report by The Royal Society and the Association for Science Education made a number of recommendations aimed at improving students' education through improving the career structure of science technicians.[65] These recommendations included:

- creating best practice guidance on the management and deployment of technical staff;
- establishing proper career and pay structures for technicians; and
- providing technicians with greater opportunities and funding for CPD, and more recognition of the skills and knowledge obtained both prior to joining, and through ongoing CPD.

2.82 The Review agrees wholeheartedly with the thrust of the Royal Society report. Science and D&T technicians have a vital role to play in underpinning and directly improving pupils' learning experiences in science and D&T. The Review therefore welcomes the Government's commitment to take forward the work coming out of this report. This should include giving technicians access to the National Centre for Excellence in Science Teaching.

Teaching assistants

2.83 The report has already commented upon the crucial role that practical work can have in improving pupils' knowledge and understanding of science and D&T, and in enthusing them to study these subjects at higher levels. Pupils' experiences of practical work are determined by the quality of the equipment and the laboratory, but also by the support, teaching and supervision they receive during the practical work.

2.84 Practical classes can be difficult to supervise and teach. Supporting the pupils in carrying out practical work can be intensely demanding for teachers. The pupil-to-staff ratio is crucial and the relatively high pupil-to-staff ratio seen in schools in England may diminish the quality of pupils' experiences of practical work, and of science and D&T more generally.

2.85 Data from OFSTED school inspections reveal that the median science class size at Key Stage 3 in England was around 29.5, with a teaching assistant present in around one-quarter of these lessons (generally to support pupils with special educational needs). At Key Stage 4, the median double award science class size was found to be around 25, with a teaching assistant present in around 15 per cent of lessons.

[65] *Supporting success: science technicians in schools and colleges*, Royal Society and Associations for Science Education, 2002.

2.86 This compares unfavourably with the situation in Scotland and Northern Ireland, which have statutory limits on the size of science classes. In Scotland, for example, no more than 20 pupils are allowed in a practical class, allowing the teacher to give each pupil more time and support.

2.87 There are a number of ways in which education in Scotland differs from that in England, and a number of factors other than pupil-to-staff ratios affect the desire of pupils to pursue study and careers in science and engineering (including the supply of science and mathematics teachers and society's attitudes to science and engineering more generally). However, it is interesting that whereas 5.8 per cent of all entrants to higher education in the UK come from Scotland, 8.9 per cent of entrants for medicine come from Scotland, 7.4 per cent in the biological sciences, 6.4 per cent in the physical sciences and 9.3 per cent in engineering. It is therefore clear that, over and above sending a higher proportion of students to higher education, Scottish students are more inclined to study science and engineering courses than their counterparts in England. (It is no surprise, therefore, that shortages of scientists and engineers in Scotland seem less acute than in other parts of the UK). The same is also true for independent schools, which also tend to have lower pupil-to-staff ratios.

2.88 A number of schools address these issues by encouraging science and D&T technicians to act as teaching assistants, which can provide technicians with valuable and interesting work. Others invite postgraduate and sometimes undergraduate students into the classroom to assist the teacher in a number of ways, including providing an extra pair of eyes, ears and hands to help support pupils in their practical work. An additional advantage is that teachers often find that an external presence makes it easier for them to teach, with fewer cases of poor pupil behaviour disrupting lessons.

2.89 The higher education sector is also becoming more proactive in helping schools in this area. One scheme which supports postgraduate students' involvement in science teaching in schools is the Researchers in Residence scheme.[66] In addition there are a number of voluntary, unpaid initiatives to encourage undergraduate students to assist the teaching of science in schools.

2.90 The Government has also sought to encourage scientists and engineers working in business, higher education and elsewhere to support students' learning experiences in science, engineering and technology, through the Science and Engineering Ambassadors Programme.

[66] The Researchers in Residence scheme is run by a number of the Research Councils and the Wellcome Trust, in collaboration with Sheffield Hallam University, and allows researchers working on a PhD to make a contribution to making school science more relevant and exciting for young people. The researchers can support the teaching of science in many ways – helping with anything from projects and practical work to careers advice for the students – as well providing excellent role models for the students. The exact role of the researcher is decided by the researcher and the school.

Science and Engineering Ambassadors Programme

This programme, launched in January 2002, is jointly sponsored by the Department for Trade and Industry and the Department for Education and Skills. It aims to encourage scientists and engineers to help in schools to:

- assist teachers to deliver the school curricula;
- run out-of-school activities, such as Clubs, schemes, awards and competitions;
- mentor groups of students and teachers;
- address school and class groups;
- support work experience placements; and, crucially,
- act as role models.

The programme is not intended to replace the existing initiatives, such as the Researchers in Residence and Neighbourhood Engineers Programme that already take people into schools. The intention is to strengthen, expand and build on them by creating a national framework.

Recommendation 2.8: Teaching assistants

The Review is convinced that the high pupil-to-staff ratios in schools in England – particularly in practical classes – is having an adverse effect on the quality of pupils' science and D&T education, and in turn on the supply of science and engineering skills. The Review believes these high pupil-to-staff ratios in practical classes are best addressed through the employment of skilled teaching assistants acting to support the teacher, and that science and engineering undergraduates and postgraduates are well placed to support teachers in this way since they have a good recent understanding not only of the subject but also of the school environment. They can also provide important role models for pupils.

The Review therefore recommends that the Government establish a major new programme, paying undergraduate and postgraduate students to support science and D&T teachers. The scheme should be implemented alongside the Researchers in Residence scheme, and should be open to postgraduates as well as undergraduates. The Government should pay students on a competitive footing with other sources of employment open to them. The Government should set an ambitious target for the number of science and engineering students participating in such a scheme by 2005.

The precise role of the teaching assistants should be for schools, universities and the students to decide locally, on the basis of guidance from the Government. Examples of possible roles could be direct support to teachers in supervising practical work, giving demonstrations or supporting science and D&T technicians. Naturally, it will be important to ensure that those participating have the skills and training to work in these capacities.[67]

Courses and curricula

2.91 The content of subjects studied and the way in which the content is presented will naturally be an important influence on pupils' subsequent choices. There is widespread concern that science, in particular, is taught in a way that does not appeal to many pupils and that the curriculum places too much emphasis

[67] The Science and Engineering Ambassadors programme could play a useful role in facilitating this recommendation.

on rote learning rather than relating theory to situations relevant to the pupil. There is also considerable concern over a number of other issues related to the course content:

- the impact of health and safety guidelines on the nature of practical work in the classroom;
- the ease with which pupils can make the transition from GCSE to A- and AS- levels;
- the perception that mathematics and the physical sciences are harder subjects; and
- the availability and take-up of measures and schemes to enhance the curriculum.

Science curricula

2.92 There has been considerable change in the style and content of science courses in the last twenty years, particularly with the advent of the double award science GCSE and the move towards ensuring that science courses – particularly at Key Stage 4 – can appeal to all pupils. The box below summarises the current aims of the curricula, and sets out changes proposed by the QCA.

Aims of the science curricula

The QCA believes that the science curricula should:

- help young people to acquire a broad, general understanding of the important ideas and explanatory frameworks of science, and of the procedures of scientific enquiry, which have had a major impact on our material environment and on our culture in general;
- seek to foster a sense of interest in science so that young people feel confident and competent to engage with scientific and technical issues and phenomena that they encounter in everyday life;
- motivate an appropriate pool of pupils to study science after the age of 16;
- prepare pupils for further study on AS/A level GCE courses in science and science-related subjects; and
- prepare pupils for further study on vocational courses in science and science-related areas.

In order better to deliver these aims at Key Stage 4, the QCA has proposed that science education should be split into a number of modules:

- Core modules, which would prepare pupils to be consumers, rather than producers of scientific knowledge, and which, taken together, would lead to a compulsory Single Award in science; and
- Applied and academic modules in a range of science options, which would bring the pupil up to a double award (or a triple award it they take all of the academic options in biology, physics and chemistry).

These courses would be piloted in September 2003.

2.93 There have been many studies in recent years of the science curriculum and its role in enthusing pupils to study science at higher levels. These studies have drawn on the views of pupils, parents, teachers and others with an interest in this area.[68] Their conclusions, which were matched by concerns expressed in the Review's consultation, were that:

- pupils are sometimes 'turned off' science by what they see as excessive repetition and too much emphasis on the volume of scientific knowledge required at the expense of discussion of potentially more enjoyable and contemporary elements of science;
- too many pupils view the curriculum, particularly those areas related to for physics and chemistry, as lacking relevance to everyday life and to topical science stories appearing in the media, and that this lack of relevance was seen as a particular issue for girls;
- the emphasis on knowledge and lack of relevance makes it hard for pupils to make a link between what they learn and potential careers;
- the curriculum is overcrowded and assessment is based too much on memorisation and recall, which is unrepresentative of how science is used later in life; and
- there are insufficient links made between issues covered in science and those covered in mathematics, ICT and D&T (in particular), which makes it more difficult for the pupil to see the close connections between these subjects, both in terms of further study and future careers.

2.94 In addition, although it was not universally the view of respondents to the consultation, studies by the Council for Science and Technology[69] and others have indicated that additional breadth in 16-18 study (for example, on the International Baccalaureate model) would be valuable to all pupils, including science and mathematics-focused pupils.

2.95 A five-yearly standards report for the QCA found that the standard of A-levels had been maintained, although to compare the equivalence of modular courses is difficult. The nature of question papers has changed in the period 1975-1995, with the mathematical content of examination questions reduced to enable greater discussion. This approach has many advantages in aiding and testing pupils' understanding, but has given rise to some concerns within higher education about the depth of pupils' mathematical abilities. These are discussed in Chapter 3 in the context of undergraduate quality.

[68] A particular study is *Pupils and parents' view of the School Science Curriculum*, J Osborne and S Collins, Kings College London, 2000.

[69] *Imagination and understanding: A report on the Arts and Humanities in relation to Science and Technology, Council for Science and Technology, July 2001.*

Recommendation 2.9: The science curriculum

The science curriculum – particularly in the physical sciences – is not, at present, sufficiently approachable nor appealing to all pupils between the ages of 11 and 16. This is a significant factor in the declining numbers of students taking these subjects at higher levels, and is widely thought to be a particularly important factor in discouraging girls.

The Review therefore welcomes both the QCA's ongoing work to modernise the science curriculum[70] and the Government's Key Stage 3 strategy. These are important elements in making the study of science more attractive to pupils, and, in turn, helping to enthuse pupils to study science and related subjects at a higher level. The Review recommends that the Government ensure that these changes deliver significant improvements to the way that the sciences (particularly the physical sciences) are taught. In particular:

- improving the ability of all pupils to relate the science they study to the world around them and to potential career opportunities;
- encouraging appropriate links to be made with other subjects (particularly D&T);
- ensuring that, while pupils continue to study the fundamental principles of science, the curricula and assessments are not dominated unhealthily by reliance on the overall volume of scientific knowledge.

The Review notes that modernising the curriculum must go hand-in-hand with providing teachers with the necessary support and training to teach the new curriculum in a way that appeals to all pupils (especially girls).

The Review further recommends that the Government should review, in three years' time, the progress in improving the attractiveness and relevance of the mathematics and science curriculum, and take further action as necessary.

Finally, the Review welcomes the QCA's proposals for reforming GCSE science, which are a necessary and positive step in increasing the appeal of science to pupils. However, it will be important to support schools and colleges in dealing with what is likely to be a more varied intake to A- and AS-level courses, and enable pupils successfully to make the transition to A- and AS-level science.

Health and safety

2.96 There is a perception amongst some that stricter health and safety regulations have directly resulted in the dropping of some of the more exciting experiments from the school science curriculum. However, discussions with teachers and others have indicated that these concerns are unjustified, although many LEAs and schools themselves are being conservative in their interpretation of the H&S regulations. While, naturally, the safety of pupils and teachers must be paramount, it is notable that, at the margin, there are few incentives on schools and LEAs to include interesting experiments with even minimal and controllable associated risks that are not mentioned explicitly in the curriculum.

[70] The QCA project, Keeping School Science in Step with the Changing Needs of the 21st Century, arose out of QCA's review of the National Curriculum. It was in response to views that constant slimming of National Curriculum orders did not provide the opportunity to review the orders with a view to updating them and making them relevant to the times and the needs of the pupils.

2.97 The Government is well placed to monitor regularly the impact of H&S regulations in schools, and ensure that sufficient guidance and support is given to teachers to enable them to use practical work to best effect. The proposed National Centre for Excellence in Science Teaching could play a useful role here in helping teachers to feel confident in trying new and more interesting experiments.

Transition between GCSE and A-level

2.98 In recent years concern has been expressed about the difficulty pupils can have in making the transition from studying science or mathematics at GCSE and studying it at A-level or AS-level. This has focussed on claims that the double award science course does not provide adequate preparation for pupils to go on to advanced study since, with less curriculum time available than if the pupil studied for GCSEs in the individual sciences, less material is covered. To address this, around 10 per cent of schools and colleges make special provision to help pupils make the transition to A-level.

2.99 A review conducted by the QCA in 1998 found that pupils with a double award background achieved – on average – between one-quarter and one-half of an A-level grade less than their counterparts who took all three sciences at GCSE. However, this tended to be true also for subjects other than science and is therefore more likely to be an institutional effect (a large proportion of those taking individual sciences are in selective schools) than one specific to science.

2.100 In addition, the changes in Curriculum 2000 should have helped to address this. However, pupils consulted during the review thought that there was still a significant step change in the education between GCSE and A-level mathematics and science (particularly in the physical sciences), although they tended to be less clear as to whether this 'jump' was bigger than in other subjects. It is concerning that pupils worried about making the transition to A- and AS-level science may decide not to study science or mathematics, and that this may be contributing to a fall in the numbers taking these subjects. The effect of AS-mathematics in 2001 is an isolated case in point.[71]

Recommendation 2.10: Transition from GCSE to A-level

The Review welcomes the proactive approach of the QCA in considering the transition from GCSE science and mathematics to AS- and A-levels in these subjects. However, the consultation process revealed that the issue may not yet have been fully addressed and the Review therefore recommends that the Government give it further consideration, and take suitable action to allow pupils to make the transition from GCSE to AS- and A-level study – particularly in the physical sciences and mathematics – smoothly.

[71] In 2001, as a result of a tough course and exam, there was a significant rise in the number of students failing the AS-mathematics exam. As a result, there has been a fall in those applying to read mathematics at university (applications are down 12 per cent this year). The Government is rightly concerned about this and the Review welcomes the emphasis that it is giving to addressing these issues quickly.

Pupil ability and achievements in SET subjects

2.101 There is a widespread belief that mathematics and the physical sciences in particular are 'hard' subjects. Given that a key determinant of whether a student chooses to continue with a particular subject is their current and expected future level of achievement (people naturally like to play to their strengths) then it is crucial to establish whether or not these subjects are indeed 'harder' than others.[72] If mathematics and science are found to be harder (or thought to be harder) then this is likely to contribute to fewer pupils studying these subjects at higher levels.

2.102 It is important that these perceptions of mathematics and science as being harder are not needlessly developed early in pupils' education – for example at Key Stage 2, where pupils' achievements in mathematics currently lag those in English significantly. The Review therefore fully supports the Government's objective to bring the standard in mathematics up to that in English by 2004, to avoid creating, at an early stage, the perception that mathematics is more difficult than English, both in the minds of pupils and in the minds of teachers and parents.

2.103 This point also applies to the GCSE examination results. Here, too, there are continuing discrepancies in the achievements of pupils in different subjects. As Figure 2.4 illustrated, the proportion of pupils achieving grades A*-C in English significantly exceeds the proportion receiving these grades in mathematics and double award science.[73]

2.104 Comparisons of achievement in mathematics with achievement in history are perhaps not as fair as, say, comparisons between mathematics and English. This is because, for example, a pupil who does not enjoy or do well in history is unlikely to choose it as a GCSE option, whereas all pupils must take mathematics and English irrespective of their enjoyment and achievement in these subjects. The same is true of the double award in science – although to a lesser extent, because pupils struggling at that stage of their education will often take single award science, rather than the double award course.

2.105 There is on-going research on the relative difficulty of A-level and AS-level courses. This research, carried out through the ALIS Project based at the University of Durham, has suggested that some subjects are harder than others at A-level. Their research has enabled them to produce trend lines for each subject to allow prediction of A-level grades from the average GCSE performance of a candidate and to show that the prior achievement levels of the intakes to the various subjects are quite different. For example, the sciences, foreign languages and mathematics enrol, on average, higher achieving students than sociology, psychology or law.

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[72] In this discussion, one subject is defined to be 'harder' than another if – for a given level of effort by a student – their expected level of achievement in the first subject is lower.

[73] Since pupils in the independent sector often still take individual sciences at GCSE level rather than the double award science course, the group of all pupils taking history should not be directly compared to the group of all pupils taking the double award science.

2.106 The research shows that the average GCSE grade is a good indicator of general abilities and provides the best available correlations and, therefore, predictions.The trend lines are different for each subject, reflecting their relative degree of difficulty. It is shown that pupils with the same GCSE profile achieve on average one grade lower in chemistry, physics and mathematics than the average A level grade obtained. The most difficult subjects are: chemistry; physics; Latin; French; mathematics; and biology (roughly in that order). Clearly the trends have to be calculated each year on that year's data to provide fair comparisons.

2.107 Given that sciences and mathematics appear to be harder subjects, there is a concern that schools could, at the margin, be encouraging their pupils to choose non-science subjects in order to raise their position in the examination 'league tables'. There is little more than anecdotal evidence to suggest that this might be the case, but it is an issue which the Review urges the Government to bear in mind.

Recommendation 2.11: Difficulty of subjects

The Review welcomes the attention that the QCA has given to the issue of inter-subject standards, and urges the Government to undertake definitive research into the greater apparent difficulty of science and mathematics A-levels and to take appropriate subsequent action. It is essential that pupils have a broadly equal chance to achieve high grades in science and mathematics as they would in other subjects. Without this, fewer pupils will choose to study science and mathematics at higher levels. The Review is firm that arguments about the merits of 'levelling up' or 'dumbing down' are a distraction – if pupils generally find it more difficult to achieve high marks in science and mathematics, this needs to be corrected. The Review believes that this can and should be done without compromising the core knowledge and skills needed for studying science and engineering courses in higher education.

2.108 A number of organisations and individuals have been in favour of financially rewarding pupils who receive, for example, an 'A' grade in mathematics, physics or chemistry at A-level. There are examples of such payments encouraging more pupils to take up particular courses. However, many in the education profession strongly object to such drastic measures, believing that pupils should be able freely to choose their subject combinations without what they see as 'bribes'.

2.109 The Review is sympathetic to these concerns and views the best approach to encouraging more pupils to take these subjects as being to improve the quality of the educational experience. The Review does not therefore recommend introducing such a scheme at this time. However, given the importance of securing a strong supply of these skills to the UK economy, this approach may need to be revisited later.

Curriculum enhancement

2.110 Pupils' enthusiasm for SET subjects within the school environment can be kindled outside the classroom as well as inside it. Visits to science and discovery centres and science-related museums and other attractions can help pupils to link the knowledge gained in the classroom to contemporary science issues, and through this help to stimulate their interest. The Government has also sought to enhance science and mathematics courses through initiatives such as Science Year,[74] a UK-wide educational initiative aimed at 10-19 year olds and their teachers, parents and other members of their community. Science Year follows 'Maths Year 2000', which attempted to do the same for maths by popularising it with parents as well as pupils, and has been succeeded by 'Count on', a campaign seeking to continue the promotion of mathematics as an enjoyable and interesting subject.

2.111 Although the Government can play its part in enhancing the curriculum, the role of private organisations and businesses in enhancing pupils' learning experiences in science, technology, engineering and mathematics is vital. Businesses and universities are well placed to help pupils relate the latest scientific breakthroughs to what they are currently learning.[75]

2.112 At present, there are some 1,200 plus national schemes, awards, competitions and other forms of resources and materials, sponsored by companies and other organisations, to support science and engineering education in schools.[76] These independently-provided schemes, awards, competitions and visits offer potentially excellent opportunities for enthusing and educating pupils in the fields of mathematics, science, technology, engineering and ICT. In particular, such schemes can help pupils to make the link between the subjects studied in the classroom and the world around them. However, from discussions with representatives from schools and the organisers it is clear that the collective impact of these schemes is not as high as it should be. Teachers often have considerable difficulty in identifying and accessing the right scheme. Furthermore, they tend to overlap considerably, with the same pupils benefiting from each scheme rather than the schemes being more widely available to other pupils.

2.113 In its report *Science Teachers: a report on supporting and developing the profession of science teaching in primary and secondary schools* (February 2000), the Council for Science and Technology estimated that only 5 per cent of such resources are actually used by schools. The review therefore welcomes the initiative, involving SETNET,[77] the Engineering & Technology Board, and the AstraZeneca Teaching Trust, which is looking at these issues.

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[74] Science Year aims to:
- create access and encourage participation in science and technology;
- demonstrate the relevance of science;
- inspire partnership and enable organisations to work together effectively; and
- build ownership and vision and to create scientific links where they might not be expected to build for the future; both for young people and for society.

[75] The Government is seeking to use these schemes to ensure that over the three years to the end of March 2004, every child under the age of 16 should have the opportunity, at least once in each Key Stage, or the equivalent, to participate in an appropriate STEM activity.

[76] For example, the Engineering Education Scheme, CREST, the Neighbourhood Engineers Programme and Techniquest.

[77] See paragraph 2.114.

2.114 The Government has sought to help schools make the most of these independently provided resources through part-funding SETNET (Science, Engineering and Technology Network), which aims to act as an enabling interface between businesses and schools through its 53 branches ("SETPoints"). SETNET will coordinate the Science and Engineering Ambassadors Programme and seeks to help schools identify the independently provided schemes that are right for them. The local SETPoints are intended to work closely with the Government's local Education Business Links Consortia.

Recommendation 2.12: Enhancing the curriculum

The profusion of independent schemes aimed at enthusing and educating pupils in science and engineering (for example, the Industrial Trust Scheme and CREST), and the lack of support that schools and teachers have in identifying those most suited to their pupils, is inhibiting the collective effect of these schemes. The Review therefore recommends that the Government establish a single recognised channel through which schools access these independently-provided schemes. This will help schools and teachers to identify the schemes most suited to pupils at different ages in different subjects, thereby lowering the burden on teachers. Without better co-ordination (and rationalisation) of the existing schemes, important opportunities and resources will continue to be wasted.

The Review recommends that SETNET and its network of SETPoints, be given this responsibility in the areas of science technology, engineering and mathematics, while still recognising the wider role of the Education Business Links Consortia in England. However, if SETNET is to fulfil this function (and deserve the additional funding that this Review recommends the Government provide), it is important that it emphasises all areas of science and engineering equally, and also that those in the science, engineering, IT, technology and mathematics communities (particularly the scientific community) accept SETNET as the channel of communication. SETNET should work with the proposed idea of a National Centre for Excellence in Science Teaching in delivering this.

Other influences on pupils' subject choices

2.115 Two main influences, outside pupil's direct learning experiences, were identified in the Review's consultation as having a significant impact on pupils' decisions to study science and engineering at higher levels: the public and media perception of science and engineering and careers advice.

Public perception of science and engineering

2.116 Much has been said on the subject of the perception of science and engineering in the UK, with a common view being that scientists and engineers have a poorer image in the UK than in other countries. This could affect both the pupils directly, but also indirectly, through parents, teachers and friends.

2.117 Qualitative and quantitative evidence does indicate that the ideas held by people in the UK of the work carried out by scientists and engineers, and of their working environment, can be outdated. The stereotype of a scientist (possibly 'different' in some way, working away in a small room on their own) is often reinforced by portrayal in the media – particularly television and film. Equally, engineers fear that their image suffers through being confused with mechanics. It is also thought by many that science and engineering have been adversely affected by association with what some see as a declining manufacturing sector. This said, other countries face similar issues. In the most recent extensive survey of people's views of different professions,[78] it was found that engineers were more highly regarded in the UK than in France, Germany or any other European country.

2.118 Nevertheless, there is a widely recognised need to improve public understanding of science. There have been a number of initiatives by the Government and independent organisations with links to science and engineering. For example, Copus, the UK Partnership for Science Communication, can provide a valuable strategic focus for science communication in all its forms, to improve connections between science and public audiences. The new Media Centre at The Royal Institution will also have a useful role in this regard. Influencing the views of a significant part of the population can only be achieved in the medium to long term, and is best done through changing the reality, not just through communication.

2.119 Ultimately, changing perceptions of science and engineering requires scientists and engineers themselves, and the organisations in which they work, to take a lead in presenting a clear and positive picture of their work. The Government can assist, by helping to bring all those with an interest together, but ultimately it is those involved in the fields of science and engineering who must take the initiative. Given the extensive ongoing activity directed at improving the public perception of science and engineering the Review does not make an explicit recommendation on this issue. However, the Review believes that its recommendations for improving the reality of science and engineering careers will have a positive effect on the public perception of science and engineering.

Careers advice

2.120 Discussions with pupils, teachers and organisations with an interest in these issues have indicated that many pupils do not receive up-to-date or accurate advice concerning opportunities arising from studying science, technology, engineering and mathematics subjects. This should not be regarded as a general criticism of the careers service in schools, as there are countless examples of pupils receiving excellent careers advice. Nevertheless, it is apparent that some pupils are being put off studying SET subjects – for example, after gaining the impression that these subjects are essentially vocational (*i.e.* you only study science to become a scientist) and act to close doors rather than open them (*i.e.* if you study science you can follow careers only as a scientist).

[78] Eurobarometer 55.2, Europeans, Science and Technology, Eurostat, December 2001.

2.121 A study funded by the Wellcome Trust[79] found that "There was little recognition that a science qualification may be as valuable a generic qualification as one in mathematics or English." This is a serious issue, particularly given the increasing breadth of opportunity for scientists and engineers, for example in ICT-related jobs, and needs to be corrected as soon as possible.

2.122 Research and responses to the Review's consultation reveal that pupils tend not to make links between GCSE science and future careers. Pupils choosing science post-16 were mostly keen on the subject. (Although in a few cases the pupil knew of specific career – e.g. medicine – they wanted to do). Those who planned not to take science further said they had based their decisions on experience of science in the classroom. This is consistent with schools often encouraging pupils to choose subjects that interest them, rather than to think about where their subject choices would take them in the future.

2.123 There have been many studies into the effect of careers advice on pupils' choices. One of the most authoritative, *Choosing Science at 16, NICEC Project Report, 2000*, examined the factors influencing pupils' choices at 16 and found a range of problems in the way in which careers advice relating to science is delivered.

- Teachers often do not see themselves as a source of information or advice about careers in science and technology – not feeling able to keep up with careers information, and instead leaving it to the careers advisers, with whom they had very little direct interaction. The highly content driven science curriculum gave no time for wider-ranging discussion about current science issues and careers.

- There is insufficient co-ordination between advisers and science departments on activities designed to enhance pupils' awareness of opportunities in science-related areas, such as parents' evenings, conventions/industry days and joint training days for careers advisers and teachers.

- The majority of the careers advisers surveyed were graduates with a humanities or social science background. Only one in ten had science degrees, with none possessing physical science backgrounds. (Such non-scientists and engineers will need more support from teachers, businesses and others in advising on science and engineering careers, whereas in fact the study found both a lack of systematic training and of updating of occupational information available to advisers.)

- Schools find it hard to secure work experience places in science and engineering for Years 10 and 11 because of insurance and health and safety issues, and a lack of local science-based employers.

[79] *Pupils and parents' view of the School Science Curriculum*, Osborne and Collins, Kings College London, 2000.

Recommendation 2.13: Improving the perception of careers in science and engineering

The Review believes that further action is needed from the Government, but also from businesses and others in scientific and technical fields, to ensure that pupils (especially girls) receive accurate and positive advice about the rewards (and the breadth of careers arising) from studying science and engineering. Specifically, the Review recommends that the Government establish a small central team of advisers (possibly within the new Connexions service, but working closely with SETNET) to support existing advisers, teachers and parents in advising pupils. Furthermore, the Government should review, in three years' time, the progress in improving pupils' knowledge of the rewards and the breadth of careers arising from studying science and engineering, and take further action as necessary.

A vision for science, mathematics, D&T and ICT education in schools and colleges

2.124 This chapter has examined how pupils' experiences while at school or further education are contributing to shortages of high-level science and engineering skills. It has shown that although pupils' levels of attainment are rising, there are a number of factors that need to be addressed in order to secure a strong future supply of scientists and engineers in the UK, including:

- improving the supply of science, mathematics, D&T and ICT teachers through improved remuneration and access to subject-related professional development;
- improving the quality of the school laboratories and equipment, and the support available to teachers and pupils in making the most of these facilities;
- modernising and improving the relevance of the school science curricula, and helping pupils and teachers enrich the learning experience; and
- assisting pupils in making positive decisions to study science and engineering subjects at higher levels and to pursue careers in science and engineering.

2.125 Delivering these improvements will require close cooperation between the Government, schools, unions, higher education and employers, with each playing an important role in fostering pupils' enthusiam for, and knowledge of, science, technology and mathematics. This means the Government providing the resources, incentives and frameworks for schools and colleges to offer technology and mathematics education that, with the help of higher education and business, captures the imagination of the pupils – girls and boys equally – and encourages and inspires them to pursue study and careers in fields which will be critical to the UK's economic success.