



Opinion Forum on Secondary Science Education: Accompanying Document

Summary

There is a crisis in secondary science and mathematics education, both in uptake of subjects and quality of teaching. It is time to take immediate and decisive action.

CaSE believes that student interest will increase most following an improvement in teaching. The shortage of specialist mathematics, physics and chemistry teachers in maintained schools is well documented. The Government has set ambitious targets to increase recruitment, retraining and retention of specialist teachers, but CaSE argues that it is unlikely to meet them without taking further steps, including the following.

The Government MUST set subject-specific goals for chemistry, physics and mathematics recruits to teacher training courses.

Headteachers should be encouraged to make greater use of existing flexibilities in remuneration where they have difficulty recruiting subject teachers. The most effective way for the Government to motivate headteachers to use these flexibilities may be to include whether a school has specialist chemistry, physics and mathematics teachers in School Attainment Tables.

Shockingly, only about three in every five new recruits are still teaching in maintained schools by the end of their fifth year in the job. An efficient way to increase numbers of teachers is to improve their retention.

CaSE believes that the most effective way to improve retention of science and mathematics teachers is to provide more support staff and technicians who themselves experience improved remuneration and career prospects.

CaSE is pleased to note the increase in numbers of technicians and it supports the subject-specific training of assistants – it is essential that their training is appropriately funded, with provision for teaching cover.

The Government is providing retraining diplomas for teachers to acquire a specialism in shortage subjects. Schools should be provided with additional funding for course fees and teaching cover and teachers should be offered financial incentives.

Turning now to student interest and performance in mathematics and the sciences, all children are required to study science GCSE. The minority (7-8%) take separate biology, chemistry and physics; the majority take these subjects combined as a double award; and just 11% take the single award. There has been a massive decline in numbers of students taking mathematics, physics, and to some extent, chemistry A levels. Performance varies greatly across school type, with those in the independent sector having greater availability of triple science GCSEs, attaining better grades and being more likely to take and do well in science A levels.

The inequity in science and mathematics education across different types of schools is indefensible, especially given the long term benefits of this education to individuals. Active steps must be taken to improve the provision and quality of science and mathematics education in the maintained sector.

Uptake of science A levels has decreased with increasing competition from other A levels, often perceived as less challenging.

CaSE calls on the Government to recognise the inequality among A levels and to increase the academic requirements of the less challenging ones. Careers advice in schools must be improved as a matter of urgency to increase appreciation of the benefits of studying the sciences.

Increased uptake of physics and mathematics A levels by girls would improve the gender balance and increase overall rates and CaSE supports measures targeting this problem, including modernising the curriculum to make it more relevant, improving careers advice, and developing ways to monitor and improve student-teacher interactions. CaSE applauds recent initiatives to improve the uptake of science among certain ethnic groups. However the money may be better spent making sure that schools serving these groups have specialist science teachers. Improved careers advice should also help by broadening the careers that different ethnic minorities perceive as appropriate for themselves.

A future Opinion Forum explores the ways to improve interest in secondary science by increasing the attractiveness of studying science, engineering and mathematics at university.

By September 2008, all pupils achieving at least level 6 at Key Stage 3 will be entitled to study triple science GCSE, although not necessarily in their own school.

CaSE believes that children should always have been entitled to study triple science. An entitlement to take time out of the school day to travel to a different school to be taught triple science by a non-specialist teacher is not likely to be very beneficial.

The practical element of science classes has been reduced for many reasons such as: large classes including pupils with behavioral problems; a lack of assistants; poor understanding of Health and Safety Guidelines; inadequate funding for large items of equipment; and unsafe and uninspiring facilities.

CaSE argues for a sustained increase in recruitment of science technicians and support staff (well paid and with an improved career structure) to help deal with large class sizes and ease the burdens on class teachers. Schools should be allowed to carry over funds for large purchases and there must be an immediate and considerable financial investment to get laboratories up to standard. A central website should support practical work, including advising on Health and Safety Issues and coordinating a national scheme to share equipment donated from universities and other labs.

CaSE strongly supports the Government's stance that science must stay part of the compulsory curriculum up to age 16, but is concerned at the roll-out of new courses following only limited evaluation. New qualifications such as the diplomas must not divide the education system, pigeonholing lower-ability students into a particular career path too young. CaSE applauds the growth of science enrichment schemes. However, most have little impact on the majority of schools or the majority of pupils, particularly those without science specialist teachers.

The declining uptake of physics and chemistry observed in the UK may seem to reflect a societal shift away from the hard sciences. Cross-cultural data suggest that technologically advanced societies have to work to improve the public (and children's) perception of the benefits of science and technology and of those working in the area. However, an apparently terminal decline in interest in further mathematics in the UK has been rapidly reversed following proactive intervention across the country. There is no reason to assume that interest in chemistry and physics would not similarly increase following appropriate interventions.

Index

Introduction: Why teach science?	5
Shortage of Specialist Teachers	6
Government Targets in Teaching	7
Increasing Recruitment, Retention and Retraining of Specialist Mathematics, Physics and Chemistry Teachers	7
1. Recruitment	7
2. Teacher Retention and Specialist Support Staff and Technicians	8
3. Retraining	10
GCSE Performance	10
A level Performance	12
Government Targets in GCSE and A levels	12
Why are declining numbers of students taking mathematics and science A levels?	13
1. Lack of GCSEs, specialist teachers, and course availability	13
2. Competition from other A levels	13
3. Dropping difficult subjects after AS levels	14
4. Inadequate careers advice	14
5. Other factors: socio-economic status, gender, and ethnic minority.	14
6. Lack of pull through from Higher Education	16
Science Practical Classes	16
The Evolving Science Curriculum	17
Enriching science teaching	18
Additional Background Information	18
Specialist Schools and City Academies	18
Psychology: Science Saviour or Soft Option?	19
Cross-Cultural Influences	19
Further Mathematics Numbers are Rising: A Case Study of Success	20
References	21

Introduction: Why teach science?

There are three main reasons to teach science. First, everyone needs to be able to understand the myriad of ways in which science affects our modern lives, and make informed choices about them, from medical care to transportation, from energy supply to food. Second, we must train those who pursue a scientific or technological career, or bring these skills to other areas, such as in the City or Law. Finally, our scientific achievements should be celebrated as an important part of our cultural heritage.

In our increasingly knowledge-based economy, it is estimated that employer demand for those with science skills will grow by 2.4 million by 2014 or more if Government targets for investment in research and development are met. For this to happen, the number of science, engineering and technology graduates needs to double, from 45,000 to 97,000 each year^{1,2}.

"...we need to ensure our education system can give young people the skills they need. This means modern laboratories where pupils can enjoy the fun, hands-on aspects of science under the tuition of teachers with the specialist knowledge to give them the depth of knowledge and inspiration they need."

John Cridland, The Confederation of British Industry Deputy Director-General, March 2007.

There is a crisis in secondary science and mathematics education, both in uptake of subjects and quality of teaching. It is time to take urgent and decisive action.

As well as a decline in student interest in science and mathematics, the size of the secondary school cohort is entering a period of decline. To achieve the necessary supply of trained scientists and mathematicians, uptake of these subjects must be increased. As year groups decline in size, it is important to make sure that science and mathematics options are not eliminated due to falling class sizes, shifting a small demographically-based decline in uptake into a precipitous fall. If the UK does not deal with this situation, it will become reliant on overseas experts or see the science-based economies move overseas, given that the most important factor in determining where multinationals invest in research and development is access to talent³.

There has been a massive amount of change in secondary science teaching, with the introduction of new syllabuses and GCSE structure, science enrichment opportunities, and initiatives to increase teacher recruitment. All this change has occurred alongside advancing scientific knowledge and more general initiatives such as specialist schools and city academies. Although most of these changes should be positive, some have been introduced without full evaluation and it is often difficult to determine their individual impact. It is easy to see why some teachers and students are overwhelmed by the constant need to adapt. While we urge the Government to pursue our proposals, it is necessary to appreciate that even positive change can be negative in impact if too many are pursued too readily, and that all change should be evidence-based.

Shortage of Specialist Teachers

CaSE believes that the largest improvement in student interest and performance will result from an improvement in teaching.

The shortage of specialist physics, chemistry, and mathematics teachers in maintained schools is well documented (specialists have a degree or additional teacher training in the subject).

- The shortage of specialists is not evenly distributed as 44% of science teachers are biology specialists, 25% are chemistry specialists, and 19% are physics specialists.
- Only 76% of mathematics teachers are specialists in the subject.
- The situation is most critical in physics. A half of all schools for 11- to 16-year-olds have one in four or fewer specialist physics teachers and a quarter of all schools have no specialist physics teachers⁴. Furthermore, a third of GCSE physics teachers do not even have an A-level in the subject. The situation for physics may further deteriorate as 39% of teachers leaving the profession in 2004 were physicists compared with 33% of those entering teaching, and physics teachers are generally older than those of other subjects.
- The lowest-attaining schools and those serving areas of socio-economic deprivation are more likely to lack specialist teachers and low ability groups are more likely to be taught by teachers without the appropriate specialism⁵.
- The quality of specialist teachers is also a concern. Overall, 56% of postgraduate trainees with UK degrees had a classification of 2:1 or above as compared with 47% for science teachers and 39% for mathematics⁶.

Shortages are likely to be exacerbated if new government proposals to increase the school leaving age to 18 become policy.

"The number of teaching vacancies in science is higher than in any other subject. This is having an adverse effect on teaching and is limiting improvements in the subject... Since 1998 the teacher vacancy rate has nearly quadrupled and in January 2005 the number of unfilled posts was 250"

The Annual Report of Her Majesty's Chief Inspector of Schools 2004/5, quoted in Ofsted evidence to Science Teaching in Schools. House of Lords Science and Technology Committee, 2005-06.

Children need to be taught by specialist teachers.

Ofsted found that the quality of science teaching relates to teachers' qualifications. This could be because the better qualified teachers are simply found in the better schools. But the relationship holds when school quality is taken into account. School-type and pupil ability are the best predictors of student uptake of physics (pupils at grammar and then independent schools are most likely to take physics). But once the students have elected to take the subject, pupil ability is the most important predictor of performance closely followed by teachers' qualifications⁷. It is easy to see how poor teaching decreases GCSE, A level, and degree uptake and grades, and this will, in turn, produce a shortage of graduates available to become specialist teachers. Urgent action is essential to prevent this downward spiral.

Government Targets in Teaching

Step up recruitment, retraining and retention of specialist teachers, so that by 2014:

- 25% of science teachers have a physics specialism (currently 19%);
- 31% of science teachers have a chemistry specialism (currently 25%);
- 95% of mathematics lessons to be delivered by a specialist (currently 88%).

Steps taken to meet these targets include:

- Financial incentives to recruit physics and chemistry teachers via Employment Based Routes;
- Develop a Continuing Professional Development (CPD) programme to give existing science teachers who don't have one a physics and chemistry specialism⁸.

Increasing Recruitment, Retention and Retraining of Specialist Mathematics, Physics and Chemistry Teachers

1. Recruitment

Why have too few specialist science teachers been recruited? Low pay is the biggest deterrent for undergraduates choosing not to follow a teaching career, and this was still an issue after the introduction of 'golden hellos' (a financial incentive of £5000 for new recruits in specialist subjects)⁹. Consistent with this, shortages are more pronounced in geographic areas and disciplines where there are higher external salaries¹⁰. The second biggest deterrent for undergraduates is pupil behaviour. Some graduates are also put off teaching because of the likelihood of teaching non-specialist subjects in combined science lessons¹¹. If the supply of specialist teachers increases and more schools return to teaching triple sciences, this factor should decrease and one could hope for a corresponding increase in numbers.

Recruitment of teachers into shortage subjects has recently increased, probably as a result of new initiatives, including 'golden hellos'. Around 3000 science teachers and 2000 mathematics teachers were recruited in 2006/7, although this is still a few hundred short of government targets. Unfortunately, the Government has significantly over-stated the number of new hires of science teachers, confusing this with the number of recruits into teacher training in science, engineering, mathematics and technology, where technology includes business studies, graphics, textiles and food technology.

"There is already some progress. Science teacher vacancies are already falling. 7,500 new science teachers were hired in 2005 - 70% more than 1999/2000."

Prime Minister Tony Blair, Our Nation's Future – Science, 3 November 2006

This misunderstanding may have grave consequences if government ministers believe the situation is far better than it actually is.

For the first time in 2006, numbers of science recruits were broken down by subject. Most recruits entered under general science, with 977 (26%) as biologists, 568 (15%) as chemists and 383 (10%) as physics specialists¹². Thus, whilst the overall increase in science teachers is positive, it is hard to see how such a small proportion of physics and chemistry specialists is going to significantly improve the situation. As a result of some of the new programs, the average age of someone starting teacher training is now 30 with 25% of all new teachers starting teaching after a first career; this rises to 42% in mathematics and 45% in science. While these new recruits should help alleviate the present crisis, the increased age of these teachers means that supply will have to be maintained as they will not stay in the profession as

long as younger teachers (although, as we shall see, retention is generally so low that this may not be a significant concern).

The Government MUST set subject-specific goals for recruiting chemistry, physics, and mathematics teachers. CaSE believes that this simple reform has great potential to improve the situation. Increasing the overall number of science teachers does not guarantee an improvement in shortage subjects unless training places are allocating to shortage subjects.

At the moment, physics or chemistry specialists might well be turned away from general science teacher training courses because they are already filled up with biologists.

“It is estimated that the physics teacher training output needs to be increased from 450 to 750 per year to offer all schools in the next five years the prospect of having at least a quarter of their teachers of physics with a qualification in physics, and to cope with the increase in retirements among existing staff.”

Smithers & Robinson (2005). *Physics in Schools and Colleges: teacher deployment and student outcomes*. University of Buckingham, The Centre for Education and Employment Research, p. 8.

An obvious if controversial proposal to increase recruitment would be to increase the pay of teachers in specialist subjects. Teachers' unions are reluctant to support this policy as it would be divisive among its members. A general salary-based solution for all 44 000 secondary science and mathematics teachers would be expensive and inefficient given that there is only a shortage in some geographic and demographic areas¹³. In fact, teachers' salaries are higher than many people perceive, starting at £20 000 for a newly qualified teacher (£24 000 in inner London) and rising to £34 000 (£41 000 in inner London) for good, experienced, classroom teachers.

Headteachers must be encouraged to make greater use of existing flexibilities in remuneration where they have difficulty recruiting subject teachers. The most effective way for the Government to motivate headteachers to use these flexibilities may be to include whether a school has specialist chemistry, physics and mathematics teachers in School Attainment Tables.

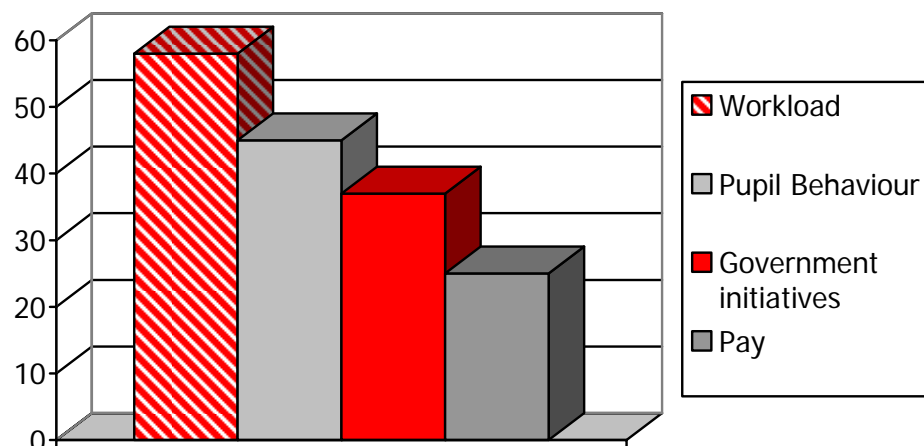
These flexibilities in remuneration include starting teachers higher up the pay scale, doubling pay increments for excellent performance, and recruitment and retention incentives.

Headteachers need to be assured of the appropriateness of these measures and the clarity with which they can be advertised¹⁴.

2. Teacher Retention and Specialist Support Staff and Technicians

Shockingly, only about three in every five new recruits are still teaching in maintained schools by the end of their fifth year in the job. Of 950 mathematics teachers graduating in 1999, 610 (64%) were still teaching in the maintained sector in 2004 and of 1860 science teachers graduating in 1999, 1150 (62%) were still teaching in the maintained sector in 2004¹⁵. Factors most frequently cited for leaving the profession were workload (58%), pupil behaviour (45%), government initiatives (37%), and then pay (25%) (see Figure 1). It is possible that retention problems will become even more pronounced when the 'golden hello' graduates reach the classrooms, given that they may have been motivated more by financial gain than a desire to teach.

Figure 1. Factors cited by teachers for leaving the profession.



Source: Teachers Leaving, NUT, 2001

A recent survey of mainstream schools found that mathematics and science teachers were dissatisfied with workload (especially heads of department) and pupil behaviour. Notably pay was not a big factor. Other problematic factors affecting mathematics teachers were poor school attainment, length of time teaching mathematics (longer was more negative) and shortages of support staff. Lack of departmental specialist staff strongly related to dissatisfaction for science teachers. In contrast, two thirds of mathematics and science technicians and support staff were satisfied with their work but only 10-25% of them were satisfied with their pay levels. Science technicians and support staff were also dissatisfied with the lack of career progression¹⁶. Where departments had dedicated support staff, teachers and departmental heads were more satisfied with the amount and quality of support received.

A survey of support staff found that technicians were among the least likely to feel appreciated and supported even though they had the most impact on decreasing workloads on teachers. Most teachers felt that support staff benefited pupil learning and behaviour:

"Technicians were therefore consistently cited by teachers as being responsible for positive effects on teacher workload, job satisfaction and levels of stress."

The deployment and impact of support staff in schools: Report on findings from a National questionnaire survey on schools, support staff and teachers, DfES, 2006, p.7.

Thus, while pay might be a significant factor for those choosing the teaching profession, those who have joined the profession are most affected by high workload and poor pupil behaviour. Again headteachers have some flexibility to increase remuneration to improve retention, but there is little evidence to suggest that this would be effective.

The Government has not focused on retention issues to the same extent as recruitment. We believe that the most effective way to improve retention of science and mathematics teachers would be to provide more support staff and technicians who themselves experience improved remuneration and career prospects.

The number of secondary school technicians has increased from 12,580 in 1997 to 19,910 in 2005 (although these figures include design technology, home economics and craft technicians). Also, a new Higher Level Training Assistant course is about to be rolled out across

the country for mathematics and science; as well as improving general teaching skills, participants develop subject-specific expertise and reported that they felt better appreciated and utilized following the course.

CaSE is pleased to note the increase in numbers of technicians and strongly supports the subject-specific training of assistants – it is essential that their training is appropriately funded, with provision for teaching cover.

A CaSE survey found that good laboratory facilities enhanced retention of teachers as well as their recruitment (see section on practical classes).

3. Retraining

Before entering into teacher training, many candidates undertake a pre-training period to develop a specialism, especially in shortage subjects. The government is proposing to introduce diplomas to enable teachers to gain a specialism in chemistry and physics later in their careers. **Schools must be provided with additional funding to cover course fees and supply teachers during this retraining and teachers should be offered financial incentives to retrain.**

The School Teachers' Review Body recommended that an incentive comparable to the 'golden hello' payment for science teachers (of £5000) was appropriate for those completing retraining in physics, chemistry and mathematics.

All teachers should have access to Continuing Professional Development (CPD). These are especially important in the sciences because of rapid changes in these subjects. However, only half of all secondary science teachers had undertaken CPD in 5 years. This may be because of poor access to courses, since most science opportunities are in the London area, and a reluctance or inability of schools to cover both the costs of the courses and supply teachers to cover. Interestingly, CPD uptake is good and increasing for technicians, who do not always require cover. In order to improve and retain the quality of science teaching it has been suggested that CPD should become mandatory, but this demand may decrease recruitment and retention of shortage specialist teachers at a time when there is a desperate need to increase numbers. It may be more appropriate to link CPD to career stages and progression.

GCSE Performance

All children are required to study science GCSE up to the end of Key Stage 4 (Year 11) at about 16 years of age. Currently, they may take triple science leading to separate exams in biology, chemistry and physics or these subjects combined as a double award (equal to two GCSEs) or single award (equal to one GCSE). Pupils can take science A levels after double science but are better prepared and more likely to do so if they have taken triple science. For instance, pupils who take triple science are 76% more likely to get an A or B grade in A-level chemistry compared to those who take double-science.

Over the last 5 years, around half of all children achieved at least a C grade in mathematics or at least one science, or both. Table 1 provides more detail of children's recent performance. In 2005, just 11% of children were entered into single science and, judging from their low achievement of A* to C grades, they would have struggled with double science. Nearly three quarters of children take double science and 57% of them achieve A* to C grades. What is striking is the small minority of children taking the traditional physics, biology and chemistry GCSEs (7-8%), although these students perform very well, with at least 90% achieving A*-C

grades. This pattern of performance has been fairly consistent over the last decade, with a small shift from single to double science, and an increase of about 10% in the number of children achieving an A-C grade in all awards except single science. The lack of grade increase in single science may reflect a positive trend to enter those students likely to attain a higher grade into double science.

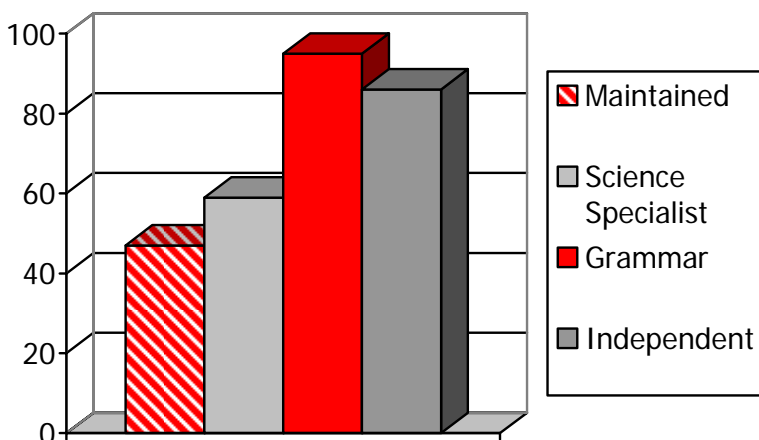
Table 1. 2005 GCSE results as a percentage of pupils attempting that subject and thousands of pupils attempting each subject

	Thousands of pupils (percentage of total)	Grade A*-C	Grade A*-G
Mathematics	605.3 (98)	55	97
Any Science	583.1 (95)	55	97
Single Award Science	65.5 (11)	20	92
Double Award Science	450.9 (73)	57	98
Physics	45.4 (7.4)	91	100
Chemistry	45.9 (7.4)	91	100
Biological Sciences	48.3 (7.8)	90	99
Other Sciences	7.6 (1.2)	52	95

Source: DfES

Performance is greatly affected by the type of school children attend. In 2002, only 19% of maintained schools offered separate sciences and those studying the sciences were less likely to gain an A grade than those in the independent sector¹⁷. For instance, while independent schools produce a third of the entries to each of the separate sciences, they gain over 50% of the A* grades, and similarly, they make up around 7% of maths GCSE entries, but over 30% of A* grades. The inequality of performance is illustrated in Figure 2, showing that the percentage of pupils gaining at least one science GCSE at at least a C grade is 47% for mainstream schools and 59% for science specialists, as compared with 95% for grammar schools and 86% for independent.

Figure 2. Percentage gaining A*-C in any science GCSE by place of study



Source: House of Lords Science and Technology Committee, 10th Report of Session, 2005-06, Science Teaching in Schools. Evidence from the DfES

A level Performance

In Year 12, a number of Advanced Subsidiary (or AS) levels can be taken and in Year 13 a smaller range of A levels are typically taken. Students accrue points according to the level and grade of their qualifications and universities typically offer places with a certain point requirement, sometimes specifying that certain subjects must be taken and certain levels attained in them. Table 2 illustrates the pattern of A level entries over the last decade. There has been a dramatic decline in students taking physics, while numbers taking biology are relatively stable and recently slightly increasing and chemistry uptake is gently declining. Mathematics has significantly declined but recently started to recover. The pattern of preference has changed massively over the last 20 years, given that in 1984, physics was the most popular science A level, and biology the least.

Table 2. A level entries for science and mathematics in English schools and colleges over the last decade (from DfES)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Biology	47,807	48,897	47,192	46,190	44,592	45,407	43,902	44,235	45,664	46,624
Chemistry	36,613	37,103	35,831	35,290	33,871	32,324	31,065	32,130	33,164	34,534
Physics	28,903	29,672	29,552	28,191	28,031	27,860	26,278	24,606	24,094	23,657
Other science	4,301	4,325	4,124	3,834	3,587	3,740	4,029	3,773	3,779	3,599
Mathematics	56,050	56,589	56,100	53,674	54,157	44,156	44,453	46,017	46,037	49,805
Further mathematics	4,999	5,211	5,145	5,015	5,063	4,498	4,730	5,111	5,192	6,516

Source: DfES (these are for students up to the age of 18 in each academic year)

Government Targets in GCSE and A levels

Government Targets in GCSE and A levels Include¹⁸:

- Continually improve the science performance of pupils at the end of Key Stage 3 and GCSE
- Increase the number of students taking science A levels so that by 2014 35,000 take A level physics 37,000 take chemistry A level and 56,000 take mathematics A level

Steps taken to meet these targets include:

- From 2007 the number of pupils achieving a C or above in at least two science GCSEs will be included in the School Accountability Framework
- By September 2008, all pupils achieving at least level 6 at Key Stage 3 will be entitled to study triple science GCSE, although not necessarily in their own school

CaSE welcomes these measures but believes that children should always have been entitled to study triple science. We are concerned about the practical arrangements for children studying at other schools and the increasing provision of “entitlements” with strings attached. An entitlement to take time out of the school day to travel to a different school to be taught triple science by non-specialist teacher is not likely to be very beneficial.

Why are declining numbers of students taking mathematics and science A levels?

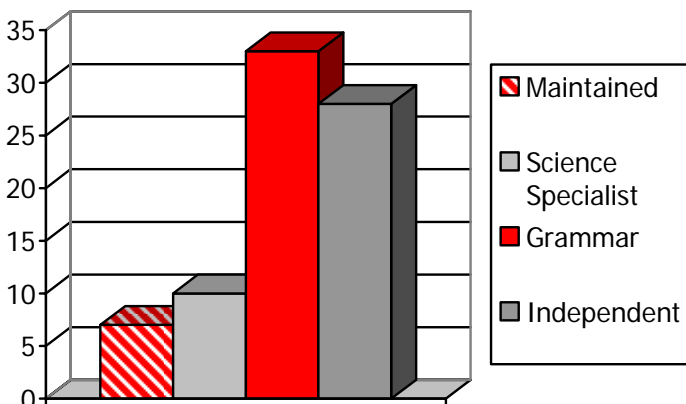
1. Lack of GCSEs, specialist teachers, and course availability

The majority of children now allocate two of their GCSE choices to science. In the past this would have been a strong foundation to continue these two subjects at A level. Now, however, children are encouraged to take triple science if they want to advance to A level (and they would be better equipped in doing so). Furthermore, if students have particular difficulty in one subject area of double science, it will affect their whole grade and may prevent them from continuing with another science at which they excel.

In schools with a shortage of specialist teachers (see teaching section), A levels may not be offered or children may have experienced poor quality teaching at GCSE which diminishes their performance and the likelihood of them wishing to pursue the subject at A level.

The proportion of students studying science and mathematics is greatly affected by where they study. About one in ten students take at least 1 science A level in mainstream or science specialised schools, as compared with about one in three at grammar and independent schools, as illustrated in Figure 3.

Figure 3. Number of 15 year olds taking at least 1 science A level by place of study



Source: House of Lords Science and Technology Committee, 10th Report of Session, 2005-06, Science Teaching in Schools. Evidence from the DfES

The inequity in science and mathematics education across different types of schooling is indefensible, especially given the long term benefits of this education to individuals. Active steps must be taken to improve the provision and quality of science and mathematics education in the maintained sector.

2. Competition from other A levels

There are now 70 subjects offered at A level many of which are clearly more attractive to students who often perceive sciences as relatively difficult, unfashionable, and boring. Students tend to choose subjects based on enjoyment, anticipated grades, and career opportunities. The excitement and enjoyment to be had from studying the sciences may well have reduced in recent years with the decline in practical lessons (see separate section). All A levels yield the same number of points for the same grades despite evidence that many of the newer subjects (such as Sociology and Business Studies) are easier than the sciences^{19,20}.

Students benefit from getting more points by choosing easier A levels, and schools and colleges may encourage them to do so because it enhances their own performance in league tables. In response to this, some universities, such as Cambridge, now require applicants to score their points in traditional subjects, and the University of Chester has started awarding double points

for Further Mathematics. Changing the allocation of points to reflect differing difficulty may improve this situation but is fraught with other complications.

The Government commented: *"the DfES and the QCA have always responded to such claims by stating that there is no such thing as an easy or hard A-level. In terms of UCAS tariff points etc. all A-levels are weighted equally. We have no plans to move from this position"*²¹.

CaSE calls upon the Government to recognise the inequality among A levels and to increase the academic requirements of the less challenging ones. On no account should the more challenging subjects be "dumbed down".

3. Dropping difficult subjects after AS levels

The provision of science and mathematics AS levels gives more students the opportunity to continue these subjects after GCSE. However, students who would otherwise have taken such subjects to A level may be discouraged by their relative difficulty and drop them after a year of study, with no stigma attached and indeed knowing that they will be recognised for their work in an AS level. There is a relatively poor continuation rate of physics and mathematics, although reliable data on this is as yet lacking²². Standardising the difficulty of A levels and providing better information on the advantages of continuing science and mathematics may improve the situation.

4. Inadequate careers advice

Only 10% of careers advisors have a background in science, and 90% said that they were not confident advising in science careers. Accordingly, students have been inappropriately advised away from the sciences because of a lack of opportunities and poor salaries. CaSE recently published an Opinion Forum on this issue. The Government has recognized the extent of the problem and pledged funds for a Careers for Science website in July 2004, but has only just delivered them.

We call for the Government to improve the quality of careers advice in schools as a matter of urgency.

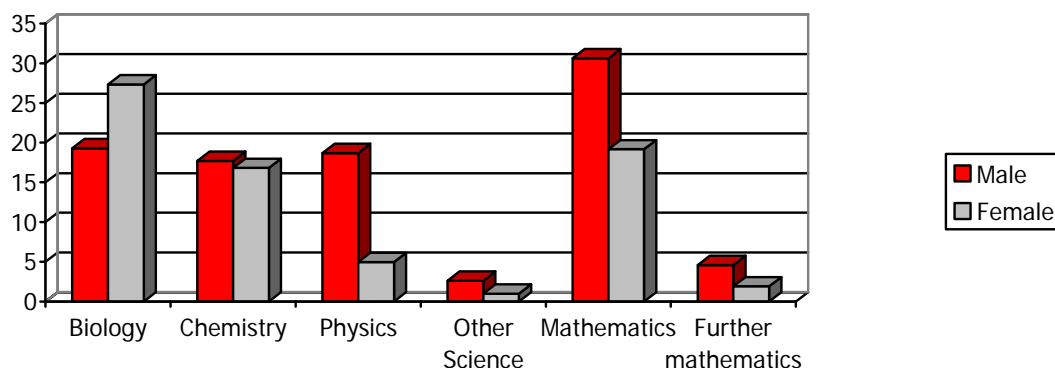
5. Other factors: socio-economic status, gender, and ethnic minority.

While socio-economic status, gender, and ethnic minority are not responsible for the decline in science A levels, understanding their influence may enable us to correct inequalities and provide insight into issues affecting all. In the study of science, socio-economic status is likely to have its main impact through access to schooling (see point 1 above), although there may also be aspirational and motivational factors.

In relation to gender, girls are under-represented in physics and mathematics, although they are over-represented in biology, as illustrated in Figure 4. These differences are not apparent at GCSE level. It has been argued that girls are affected by lack of role models and stereotyped examples, they may be less inclined to take harder subjects, and they are particularly affected by teaching quality²³. In addition, there is evidence that girls are treated differently from boys, especially in science classes. Teachers devote more time to boys than girls, have higher expectations of boys in science, and give boys more credit than girls for the same performance. While boys are often criticized about behaviour, girls are criticized about academic performance and this may negatively affect how they perceive their abilities and the likelihood of pursuing subjects. Girls may also be more inclined to want sociologically and personally relevant work that they judge to be of value. Interestingly, cross-cultural comparisons (see separate section) show that gender differences are common among more developed countries, but less apparent among developing countries. Thus while subjects such as physics and engineering may be perceived as critical in developing societies and are popular with girls among them, biological,

environmental, and medical subjects are perceived as more valuable in more developed societies, and girls move into these areas.

Figure 4. Thousands of A level entries in Science and Mathematics in England in 2005/6 shown by subject and gender



Source: DfES, 2006

Increased uptake of physics and mathematics A levels by girls would even out inequalities and increase overall rates. CaSE supports any measures targeted at this problem, including modernising the curriculum to make it more relevant (see curriculum section) and improving careers advice. In addition, it is important to develop ways to monitor and improve student-teacher interactions, possibly as part of CPD.

There is an interesting relationship between ethnic background and science uptake that illustrates the many different determinants of performance, such as eventual choice of career and socio-demographic profile^{24,25}. In order to continue to science A level, students need to achieve five GCSEs of at least grade C. Chinese and Indian pupils perform best at this stage, followed by white pupils, whilst children from black Caribbean, Pakistani and Bangladeshi backgrounds perform less well. At A and degree level, black African, Indian, and Chinese students are over-represented, compared to white students, whereas black Caribbean and Bangladeshi students are under-represented in the sciences. Broadly speaking, this pattern is even more pronounced if the numbers of students achieving at least three science A levels are compared. Chemistry is unusual in being a traditional science favoured by ethnic minorities, possibly because it is required for medicine courses given the strong bias to this discipline shown by most ethnic minority groups and especially Asian ones. Overall, ethnic minority students tend to favour computing and technology courses with the exception of black Caribbean students who prefer arts, social sciences, and humanities.

In an attempt to improve the uptake of science among certain ethnic groups, the Government Science in Society Program enables schools with a high proportion of Afro-Caribbean, Bangladeshi, or Pakistani pupils to bid for funding for extra-curricular science learning activities (providing £1.5 million from 2005-2008).

CaSE applauds such initiatives but believes that the money may be better spent making sure that these schools have specialist science teachers. Improved careers advice should broaden the careers that different ethnic minorities perceive as appropriate for themselves.

6. Lack of pull through from Higher Education

The Government allows UK universities to offer courses in response to demand. This market-driven approach, combined with inadequate funding for laboratory based sciences, has led to the closure of about 20 physics and 30 chemistry departments over the last decade. The Government must recognize the need to guarantee a future supply of scientists, mathematics, and engineers, and intervene in higher education to achieve this. In another Opinion Forum on this subject, CaSE argues that it is essential for the future health of science in the UK to provide adequate funding and financial incentives for students (such as reduced course fees and student debts). As more students plan to take these subjects at university, A level uptake should correspondingly increase.

Science Practical Classes

The practical component of science courses teaches students fundamental skills and is highly motivating for them, influencing their later choice of subjects. The quantity of practical work is at the discretion of teachers and, sadly, there is much evidence from surveys performed by CaSE and other sources that the majority of teachers are reducing both the quantity and variety of practical work for a number of reasons^{26,27}:

- Class sizes are too large and behavioral problems are particularly pronounced and dangerous in practical lessons
- Lack of assistants and preparation time
- Poor understanding of Health and Safety Issues and Guidelines
- Inadequate funding for large items of equipment
- Unsafe and uninspiring facilities

It is straightforward to tackle most of these points. Although it would be desirable, imposing a requirement on schools to reduce the number of students in practical classes may produce scheduling problems and lead to a further reduction in the number of classes.

Instead, CaSE supports a sustained increase in recruitment of science technicians and support staff (well paid and with an improved career structure) to help ameliorate the large class sizes and ease the burdens on class teachers.

As discussed in the section on teacher retention, presence of a specialist support teacher improves student behavior.

Teachers need to be provided with accurate Health and Safety information and appropriate support. The Consortium of Local Education Authorities for the Provision of Science Services (CLEAPPS) reported that the majority of calls to a helpline for members concerned practical work, and about a sixth simply concerned whether an activity was allowed or not. Regarding equipment and facilities, the Royal Society of Chemistry found that 66% of school laboratories were rated as basic (uninspiring) including 25% that were unsafe or unsatisfactory, and it estimated that £1.38 billion would be required to upgrade all to a good standard. There are also too few laboratories, with an average of about 1 more needed in each school. The Building Schools for the Future programme aims to replace or refurbish all secondary schools by 2020 but funding needs to be specifically earmarked for laboratories and it has been announced that the £200 million pledged in the run-up to 2005 Election will not now be delivered. Depressingly, new builds and refurbishments are reportedly of poor quality and occurred without consulting expert groups (e.g., CLEAPSS and the Association for Science Education)²⁸. As well as improving practical experiences, a CaSE survey found that good laboratory facilities enhanced recruitment and retention of teachers²⁹.

A considerable financial investment is essential to get laboratories up to standard. Schools should also be allowed to carry over funds to make more significant purchases. In addition a central website should be formed to support practical work, including advising on laboratory requirements, Health and Safety Issues and coordinating a national scheme to share equipment donated from universities and other labs.

"Science is a practical subject, so if you are not doing that, you are not doing science."
Dr Peter Cotgreave, Director of CaSE, 23rd March, 2007, Times Educational Supplement.

The Evolving Science Curriculum

CaSE strongly supports the Government's stance that science must stay part of the compulsory curriculum up to age 16, but it must be backed up by appropriate policies to make it meaningful.

While some of us are just getting used to single, double and triple science GCSEs, new ranges of courses have been introduced. For example, three 21st Century Science courses were launched in September 2006, having been developed by the Nuffield Foundation and University of York to increase young people's engagement with, and literacy in, science. Previous courses had been judged to be tired, lacking in relevance and too focused on the needs of future scientists rather than the general population.

An introductory course, *Science*, provides scientific literacy for all students, covering data limitations, correlation and causality, developing explanations, the scientific community, risk and decision making. It is exciting to think of a generation well equipped in these areas. *Additional Applied Science*, is intended to provide more vocational skills, and *Additional Science*, has concept-led science in preparation for A levels. Students learn through discussion, debate, role play and group work, from a range of sources including media coverage to consider moral and ethical issues as well as the science.

Unfortunately, the courses have been rolled out before being fully evaluated, and new A levels are due to start in 2008. It is ironic indeed that courses intended to teach the ability to evaluate evidence have been introduced before their own impact has been properly assessed. While many students and teachers report a higher level of engagement, there are concerns that the new courses lack challenge for the higher level students³⁰. There is a risk that the courses do not carry the intellectual rigour of the traditional courses and that we will create a population keen to engage in lively debate of scientific issues but without the background to do so competently.

As well as these new courses, straight Biology, Chemistry and Physics are still available, so schools can offer various combinations of 6 different GCSE science courses. Inevitably, the actual options available are limited by staffing and timetabling issues.

Another development, from 2008, is the introduction of new specialised diplomas, including work experience, to provide "real world" knowledge and skills, for students of all abilities, aged 14-19. Level 1 will be comparable to 4-5 GCSEs, and the highest, Level 3, will be equivalent to two A levels. The first diplomas to be offered include engineering, information and communication technology, and health and social care.

There is a risk that diplomas may divide the education system, pigeonholing some lower-ability students into a particular career path too young. We support a broad diploma system or International Baccalaureate for 14-19 students which allows them to keep their options open rather than being forced to study an excessively narrow range of subjects at too early an age. This would ensure that students

receive a more rounded education and do not over-specialise before they have seen the merits of pursuing science and mathematics.

Enriching science teaching

There has been a massive increase in initiatives to enrich secondary science learning. These include, Science Learning Centres, the Science and Engineering Ambassadors Programme, Researchers in Residence scheme and the Royal Society's Partnership Grants scheme. One example is the Real World Science Project that works with museums, curators, scientists, and secondary science students: 40% of visiting students "felt that their feelings towards science had changed positively as a result of their museum visit", and 13 per cent responded that they "had been inspired to continue studying science"³¹. Another example is the 250 after-school science and engineering clubs that were launched in March 2007 to particularly engage capable pupils who were not performing as well as they could in science.

CaSE applauds the growth and variety of these schemes, although they need to become better coordinated and hopefully will be by the formation of the Regional STEM Support Centres to provide a single, simple source of information. In addition, the contribution of academics must be recognized in their own assessments (the Research Assessment Exercise or its replacement) and schemes should be properly evaluated.

CaSE is concerned, however, that the Government frequently refers to these schemes when asked what it is doing to improve the uptake of sciences in secondary schools. While they are undoubtedly beneficial for those concerned, most depend on the interest and enthusiasm of the teachers already in place and some of the schemes are not intended for all pupils.

Most of these initiatives will have little impact on the majority of schools, and certainly on the majority of pupils, particularly those without science specialist teachers.

Additional Background Information

Specialist Schools and City Academies

As well as meeting National Curriculum requirements, Specialist Schools must have a special focus on the subjects relating to their chosen specialism. At the start of 2007, over 2,500 (over 75%) of secondary schools were specialist schools, of which 334 had science as one of their specialisms and 656 schools had technology or engineering. Overall, around 40% of specialist schools have science as a compulsory target setting subject and 58% have mathematics. Specialist schools raise £50,000 in private sector sponsorship and receive twice that from the Government. In return, they have a four-year school and community development plan to raise standards, increase provision and encourage take-up in their specialism.

The Academies program is designed to replace poorly performing local authority secondary schools, typically in cities or urban areas, where deprivation is significant. The government's intention is to establish a total of 200 academies, by 2010, 60 of them in London. This expanded program has been embarked upon, before it is clear how effective the first academies have been in elevating performance, especially in respect to the amounts invested. The academies are controversial because a school must raise up to £2 million from private sponsors; the government pays the rest of the start-up costs (in the order of £25m) and running costs. The sponsors have included individuals, voluntary organisations, worshipful companies and corporate bodies, and are given considerable powers over the curriculum and general

management of the school. It is important to monitor the scientific content of the curriculum in the academies after a Gateshead Academy included creationism in biology lessons.

Psychology: Science Saviour or Soft Option?

Psychology is often cited as one of the easier and more attractive A level subjects that lures away potential students from the sciences. It certainly seems to be an attractive option. In 2006, 48,571 16-18 year old students in England took A level psychology (making it the 4th most popular subject) and 70,155 students took AS level (making it the 3rd most popular subject). There is evidence to suggest that it is mid-range in difficulty, making it easier than the core sciences but comparable with most other A levels.

An alternative position would be to argue that A level Psychology is advantageous in increasing undergraduate science uptake because students who go on to study undergraduate Psychology are typically classified as scientists (although, sometimes as life or social scientists depending on departmental emphasis). Thus, instead of mourning decreasing numbers of science A levels, we should be celebrating the success of psychology in encouraging a massive uptake of science. The awarding bodies themselves are inconsistent in classifying A level psychology: in 2001, two included the subject in the science suite, while the other classed it as a social science. All three syllabuses require analysis, investigation, research skills and methodological awareness. Furthermore, around 20% of the marks were for practical assessments. Syllabuses cover a range of psychological areas including brain and behaviour and physiology. It is hard to see why it is considered "less scientific" than the biological sciences³². Even if students do not go on to study psychology or other sciences at university, they will have considerably increased their general scientific skills (as well as their psychological insight, of course).

Cross-Cultural Influences

Falling student interest in science and technology is a problem throughout Europe and the US. Generally speaking, the "harder" sciences, like physics, engineering, technology and to some extent chemistry are most affected. A multinational project to assess the engagement of 15-year-olds with the sciences found a generally positive view³³. Most students believed that science and technology were important for society. However, overall, students were less inclined to agree that the benefits of science were greater than its harmful effects, and in England students were pretty neutral on this point. On both these measures, there is a fascinating correlation between a countries' Human Development Index (a measure of income, education and health) and responses, with less developed countries being more positive about science. This difference was even more striking in responses to whether the children would like to become a scientist or technologist, boys and to a lesser extent girls in developing countries said that they would like to work in science or technology. In contrast, most children in more developed countries said that they would not like to be scientists, especially girls. The gender difference is more pronounced in technology: most boys in developed countries were neutral on working in technology whereas girls were decidedly negative. It is suggested that these jobs are highly valued in developing societies. More developed societies are more likely to emphasise values such as democracy, environment and care for others, consistent with the retention of interest in disciplines such as biology, medicine, and environmental studies, areas often particularly favoured by girls.

These cross-cultural data suggest that technologically advanced societies may have to work to improve the public (and especially children's) perception of the benefits of science and technology and of those working in the area.

Further Mathematics Numbers are Rising: A Case Study of Success

Numbers of students taking further mathematics A level fell from around 15,000 in the early 1980s to 5,000 by the late 1990s. Some schools and colleges stopped offering further mathematics because of small classes and staff shortages. Because of this, Universities realised that they could not specify further mathematics as an entry requirement and, inevitably, because it was no longer a requirement, more centres stopped offering it, and so on... The decline of further mathematics was particularly evident in the state sector, causing a serious equal opportunities issue. In addition, the eventual reduction in mathematics graduates would have fed into the teaching shortage. Many felt that further mathematics had reached a state of terminal decline.

In an attempt to reverse this decline, the Further Mathematics Network was formed to promote and support the subject. Since then AS further mathematics numbers have increased across the UK by 25%, and over the past two years by an impressive 58%. Increased uptake at AS level, has fed into A level further mathematics numbers increasing by 23% across the UK, and A level mathematics numbers increasing by 6%³⁴.

The Further Mathematics Network consists of 46 regional centres, coordinating schools, colleges, local authorities and universities to work together to support students studying Further Mathematics, even if their school or college do not offer it. Over 500 students were taught by the network last year, using regular face to face lessons, extensive online resources, e-mail support, and revision days. The network also raises the awareness of the benefits of studying both mathematics and runs enrichment events for pupils at Key Stage 4. The increased uptake of the subject means that it may be re-introduced into many schools and sixth form colleges.

"The Further Mathematics Network can justifiably claim to have had a significant impact, not only on entries to the subject, Further Mathematics, but also on participation in mathematics more generally. What is the key to the Network's success? ... not to take the decline as inevitable but rather proactively to find a solution by coming up with a judicious mix of high quality materials, distance learning and face to face mentoring."

Professor Celia Hoyles, DfES Chief Adviser for Mathematics

The declining uptake of physics and chemistry observed in the UK and many similar countries may seem to reflect a societal shift away from the hard sciences. A similar, apparently terminal decline in interest was perceived in mathematics education but there has been a rapid boost in interest and uptake following proactive intervention across the country. There is no reason to assume that interest in chemistry and physics would not similarly increase following appropriate interventions.

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