Consultant Report

Securing Australia's Future

STEM: Country Comparisons

This report can be found at www.acola.org.au

A study of Science, Technology, Engineering and Mathematics education in the United Kingdom

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Executive summary

According to a recent international comparison of education systems, the UK is ranked sixth best in the world. The UK's higher education system was ranked 10th (out of 48) in the 2012 *Universitas 21* assessment based on resources, environment, connectivity and output. However, an analysis of international comparisons of student attainment suggests that the UK has a relatively long tail compared with many other developed countries. That is, the gap between the highest attaining and the lowest is greater than might be expected of an education system that has undergone significant and prolonged change.

The introduction of a National Curriculum in the late 1980s and the associated assessment regime has been the major driver of teaching and learning. The culture of 'league tables' of schools has resulted in schools adopting a number of strategies designed to enhance their performance. Teaching to the test is now more common than ever and students are entered for examinations that are seen as easier to gain a high grade. These approaches have impacted on STEM subjects and have led to lowered student interest during secondary education, a decrease in high quality investigative practical work and a reluctance to release teachers for professional development.

All students now study science to age 16 which was not the case before the National Curriculum was launched. All students now study all three sciences, whereas before it was common to study only one or two. Boys tended to take the physical sciences and girls tended to take biology. The removal of compulsory national tests in science at age 11 has led to a decrease in the amount of science taught in primary schools.

While GCSE and A level pass rates have increased over recent years, there is some debate about whether standards have actually risen or not.

Recent initiatives to improve attainment in STEM subjects show relatively little evidence of success at secondary level but had some impact at primary level. However, teaching has tended to be more formulaic and 'safe' as a result of the implementation of National Strategies. The impact of STEM initiatives in the informal sector have not been adequately evaluated.

There is a strong socio-economic bias in STEM subjects as there is in other areas of the curriculum. Around 7% of students are in independent schools however, 25% of science A levels are taken by independent school students. Students from independent schools are disproportionally represented at the elite universities.

Gender differences still exist in science and mathematics particularly in physics despite numerous initiatives to address the issue.

Changes in the curriculum and assessment regimes coupled with a major increase in the proportion of students attending university mean that comparisons over time are difficult and should be treated cautiously. Arguably these high level system-wide changes are more important than the individual STEM initiatives that we report in Section 5. At the least they mean that ascribing changes to those individual initiatives is difficult.

Section 1. Introduction

This report provides a summary of Science, Technology, Engineering and Mathematics (STEM) and STEM-related issues in the United Kingdom. It is designed to inform the ACOLA ARC LASP Program *Securing Australia's Future* Project #2.

The brief for the report asked that we include, but should not be limited to, considerations of government policy, and strategy and programmes. In preparing the report, we have examined national STEM reports and studies and we focus on:

1.1 Attitudes towards STEM, and the priority given to STEM, in: families, the community/media, government, educational institutions, employers and professional bodies.
1.2 The perceived relevance of STEM to economic growth and well-being.
1.3 Current patterns of STEM provision in schooling, including STEM in primary education, and its influence on later participation in STEM; enrolments in STEM disciplines in secondary education; STEM provision, and participation, in tertiary (university and non university) education; and trends since 2005 in those secondary and tertiary enrolments.
1.4 The role of STEM disciplines in both general education and vocational and occupationally-specific programs in education and training.
1.5 Student uptake of STEM programs and factors affecting student performance and motivation.
1.6 Access of STEM graduates to the labour markets, and labour market take-up of STEM knowledge and skills.
1.7 Strategies, policies and programmes used to enhance STEM at all levels of education, and judgment concerning the success of those programmes.

Section 2 examines the perceived relevance of STEM to economic growth and well-being and presents the 'official' view which directly links STEM, the economy and well-being, and alternative views which take account of the public perceptions of STEM.

Section 3 looks at the uptake of STEM in education and describes the UK education system and the National Curriculum and assessment systems in some detail.

Section 4 examines the access of STEM graduates to labour markets in the UK and, again, provides two narratives: firstly the government and science lobby views and then a counter-narrative based on empirical research.

Finally, Section 6 provides a commentary on a number of STEM initiatives that have been introduced into the formal and informal sectors over recent years.

Section 1. The perceived relevance of STEM to economic growth and well-being

2.1 The 'official' view: STEM, the economy and well-being

'*The best way for the UK to compete, in an era of globalisation, is to move into high-value goods, services and industries. An effective science and innovation system is vital to achieve this objective'* (Lord Sainsbury, quoted in *The Race to the Top: A Review of Government's Science and Innovation Policies, 2007, p.3*). *The Race to the Top* was a review of the government's science and innovation policies commissioned by Gordon Brown, then Chancellor of the Exchequer, as part of the 2007 Comprehensive Spending Review. The comment captures the essence of the 'official' view of the economic relevance of STEM to the UK. It is a view that has been held consistently for many years by governments of both parties, by the institutions that represent science and technology, by learned societies and by industry.

Over the past twenty or so years numerous policy reports and reviews have explored and expanded on this thesis. Historically, a key document is the Treasury Ten-year review: *Science & Innovation Investment Framework 2004-2014*. This report, commissioned by the Labour Government, set the long-term policy agenda for STEM in the UK. Many of the review's recommendations have been implemented and few of its assumptions have been challenged. It still captures the essence of the official policy position.

> *The nations that can thrive in a highly competitive global economy will be those that can compete on high technology and intellectual strength - attracting the highest-skilled people and the companies which have the potential to innovate and to turn innovation into commercial opportunity. These are the sources of the new prosperity.*
>
> *This is the opportunity. This framework sets out how Britain will grasp it. It sets out how we will continue to make good past under-investment in our science base - the bedrock of our economic future. More than that, it sets out not only how we intend to invest in this great British asset - the world-class quality of our scientists, engineers and technologists - but how we will turn this to greater economic advantage by building on the culture change under way in our universities, by promoting far deeper and more widespread engagement and collaboration between businesses and the science base, and by promoting innovation in companies directly.* (p.1)

The review sets out some long-term ambitions:

World class research at the UK's strongest centres of excellence:

- *Maintain overall ranking as second to the USA on research excellence, and current lead against the rest of the OECD; close gap with leading two nations where current UK performance is third or lower; and maintain UK lead in productivity;*
- *Retain and build sufficient world class centres of research excellence, departments as well as broadly based leading universities, to support growth in its share of internationally mobile R&D investment and highly skilled people*

Greater responsiveness of the publicly-funded research base to the needs of the economy and public services:

- *Research Councils' programmes to be more strongly influenced by and delivered in partnership with end users of research;*
- *Continue to improve UK performance in knowledge transfer and commercialisation from universities and public labs towards world leading benchmarks*

Increased business investment in R&D, and increased business engagement in drawing on the UK science base for ideas and talent:

- *Increase business investment in R&D as a share of GDP from 1¼ per cent towards goal of 1.7 per cent over the decade;*
- *Narrow the gap in business R&D intensity and business innovation performance between the UK and leading EU and US performance in each sector, reflecting the size distribution of companies in the UK*

A strong supply of scientists, engineers and technologists by achieving a step change in:

- *The quality of science teachers and lecturers in every school, college and university;*
- *Ensuring national targets for teacher training are met;*
- *The results for students studying science at GCSE level;*
- *The numbers choosing SET subjects in post-16 education and in higher education;*
- *The proportion of better qualified students pursuing R&D careers;*
- *The proportion of minority ethic and women participants in higher education*

Sustainable and financially robust universities and public laboratories across the UK*:*

- *Ensure sustainability in research funding accompanied by demonstration by universities and public laboratories of robust financial management to achieve sustainable levels of research activity and investment*

Confidence and increased awareness across UK society in scientific research and its innovative applications:

- *Demonstrate improvement against a variety of measures, such as trends in public attitudes, public confidence, media coverage, and acknowledgement and responsiveness to public concerns by policy-makers and scientists*

Our focus in this report is on the fourth and sixth of these objectives (strong supply of scientists; increased public confidence) but it is worth saying a little about the others as they set the science policy context in which the educational developments are situated. While these ambitions have not all been realised, they have been strongly influential in setting the policy direction and have been pursued with seriousness by governments of both sides. Each of the themes outlined above could be the subject of substantial review in its own right. None is uncontroversial. But in summary:

- the science research budget was significantly increased in the middle of the decade and that increase has been maintained during the economic downturn;
- a policy of concentration of research funding in the most highly rated research centres has continued and indeed intensified;
- there has been substantial investment in infrastructure;
- there has been increased focus on funding research that is of demonstrable economic or social benefit;
- science communication and public engagement with science activities have grown, with conceptual if not always financial support from government, creating a wealth of science activities ‘outside the classroom’.

None of the high level reasoning in the document will come as a surprise to Australian colleagues. The Australian policy documents we have been shown in preparing for this report express very similar sentiments. There are some themes that are all but identical. For example:

1. Globalisation, and in particular the growth of the Asian economies is a key driver: *'Globalisation brings opportunities and challenges. It provides UK companies with access to new and larger markets, cheaper intermediate goods and lower prices for consumers, but many of our companies have to compete with companies in emerging economies, such as China, with wage costs that can be 5 per cent of the UK's' (Sainsbury, p.3).*

2. Linked to this, the framing of the issue in competitive terms: '*Company strategies based on low costs alone will end up in a downward spiral, each year bringing a new low-cost competitor. The best way for the UK to make the most of globalisation opportunities is to support the restructuring of British companies into high-value goods, services and industries. We should seek to compete with emerging economies in a 'race to the top' rather than in a 'race to the bottom'* (ibid). (A similar US policy document: *Rising Above the Gathering Storm*, turns the rhetoric up another notch).

3. The importance of highly trained STEM personnel: '*There is a global perception that a workforce with a substantial proportion educated in Mathematics, Engineering and Science (MES) is essential to the future*' (*Mathematics, Engineering and Science in the National Interest*. Office of the Australian Chief Scientist May 2012, p. 6).

4. A worry that the supply of science graduates is inadequate: '… *we are not alone in facing the issues we face, and that many countries are now taking substantial action as they attempt to reverse the trend of declining interest from students at the exact time that the demand for these skills in the workforce is increasing*' (ibid p 4). *'The UK has a reasonable stock of STEM graduates, but potential problems lie ahead'* (Sainsbury, p.6).

5. And that the solution lies in action at schools and in HE, particularly the former: '… *the Government's overall ambitions are to achieve a step change in: the quality of science teachers and lecturers in every school, college and university; the results for students studying science at GCSE level; the numbers choosing SET subjects in post-16 education and in higher education; and the proportion of better qualified students pursuing R&D careers*' (Treasury Ten-Year review, p. 12). '*Students' experiences at an early age have a significant impact on their future choices and there is widespread concern that pupils are turning away from STEM subjects following their experiences at school. At A-level the take-up of key subjects is a cause for concern'* (Sainsbury, p. 97).

Arising from these reports are some common themes, for example the tendency to frame the issue in terms of a pipeline; and a mildly hysterical preoccupation with the results of large-scale international comparative studies, especially TIMSS and PISA.

As well as these common themes there are aspects that are specific to the UK, in particular:

- The comparative strength of UK STEM research. This has been much discussed in recent years. See, for example: *The Scientific Century, securing our future prosperity* (Royal Society, 2010, pp. 9–11).

- The international strength of research in UK universities. See, for example, the *Select Committee on Science and Technology 2nd Report of Session 2012–13* (House of Lords 2012). We refer to this document several times in this report.

- The historic weakness of the UK in turning science into technological innovation. See Sainsbury (*passim*) for a discussion of this issue. Sainsbury argues that the UK's record has improved in recent years.

- The increasingly important role of the Europe Union (and the UK's perpetually uneasy relationship with it). The aim of the Lisbon agenda, adopted in 2000, was by 2010 to make the EU 'the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion'. Its lofty aims were not achieved, but the policies and investments in science and technology that followed were influential and the UK has benefited disproportionately from them.

- Particular weaknesses in our school and HE systems. We discuss these in some detail below.

2.2 Alternative views: Public perceptions of science in relation to economic growth and well-being

Public attitudes towards STEM have received significant attention in the UK, with many dating the start of the 'public understanding of science' movement from the launch of the Bodmer Report in 1985 (Royal Society). The public understanding of science movement was set up by the science lobby in response to rising concerns that there was a general public mistrust of, and apathy towards science. Over the following decades considerable resources have been expended with the various aims of informing the public about science, engaging the public with science, improving public attitudes towards science and measuring public views towards science.

The most up-to-date public data with a nationally representative sample comes from the government commissioned Ipsos MORI surveys 'Public Attitudes to Science' (see, for example, Ipsos MORI 2012). In relation to public perceptions of the relationships between science and the economy, the Ipsos MORI report (2011) suggests there is strong support for the view that science contributes directly to the economy, and to the growth of the economy. The links between science (which is referred to in the study as 'science' rather than 'STEM') and the economy appear to be less clear to the surveyed public, with little public awareness of how links between science and business might operate, or understanding of how science might create jobs. For instance, participants were unclear about the outcomes of scientific research, how it could lead to concrete applications and how these could affect the economy.

Despite this lack of clarity, the study suggests that the public perceive science as important for the long-term growth of the UK economy and in terms of the ability of the UK to compete in international markets. In this sense, study participants reflected the 'official' view of the role of science in the economy. It is, however, also worth noting aspects of more sceptical views found by the study. For example, science was perceived by some participants as benefitting the rich more than the poor, a view more common to participants from poorer backgrounds. Furthermore, scientists working in business environments were seen as less trustworthy than those working in academia. It should be noted, therefore, that the study did not reveal blanket support for science, nor were participants clear or well-informed about links between science and the economy.

The Ipsos MORI (2011) study also suggests that public attitudes towards the relationships between science and well-being are far from clear. When asked to describe what they understood science involved, the majority of participants listed school subjects (biology, chemistry, physics), followed by health care and medicine, with a few other disciplines being listed after these. This finding suggests a strong association between health and the sciences. It does not, however, suggest any reason for the link in the public's consciousness. For instance, as Bauer has argued (2009), science reportage has, in the last 30 years, become increasingly medical. Public focus on health as a key part of science may also stem from life-stage. Ipsos MORI found older people were more concerned with the potential for science to contribute to their health, while young people perceived science as benefitting their lives through the development of digital technologies or home improvements. In a broader sense, participants agreed overall that science could provide benefits for society, but were split down the middle as to whether the social benefits of science did more harm than good. These findings, supported by considerable research on public perceptions of risk, controversy and science in everyday life (see for example Michael, 2006; Wynne, 1996), suggest that while on a personal level participants were interested in the benefits science could provide, at a societal level, the risks of science were understood as equivalent to the potential benefits.

The study suggests participants were ambivalent about science education in schools, with their attitudes depending in large part upon their views of their science teachers, a finding reported elsewhere in the British science education literature (Osborne, Simon, & Collins, 2003). Nonetheless, the report found that half the participants had been involved in a 'science-related leisure activity' (Ipsos MORI, 2011, p. 57) in the previous year. In this sense, therefore, while not explicitly raised in relation to the role of science in society, participants were evidently involved in cultural, educational and social aspects of science in their leisure time, which represents another facet of the relationships between science and well-being. This finding is backed up by research from the UK on the benefits of participation in science based leisure activities that also suggests that people receive cultural, educational and social benefits through visits to botanic gardens, science centres, zoos and similar institutions (Department for Culture, Media and Sport, 2011; Falk et al., 2012; The Association for Science and Discovery Centres, 2010).

Section 3. The uptake of STEM in education

3.1 The UK education system

We begin with a short overview of the UK education system. Section 3.2 gives some international comparative data. Section 3.3 describes the position of STEM in the UK education system.

3.1.1 Background

Each of the four countries of the United Kingdom has its own school system, with power over education matters in Scotland, Wales and Northern Ireland being devolved. In practice the systems in England (population 53m), Wales (3m) and NI (2m) are similar to each other. Scotland (5m) differs in important respects, in particular at upper secondary level. In this report school level data usually refer to England or to England and Wales combined.

Across the UK as a whole there are some 22,000 primary schools and 4,000 secondary schools. The cohort size for 16-year-olds is around 650,000.

3.1.2 Schools

Children must receive a full-time education from the age of 5. More than 99% of children receive that education at school with the rest being home-schooled. After 2013 the school leaving age will rise to 17 and from 2015 it will rise again to 18. The requirement will be that students have to be in some form of education, not that they have to attend school or college full-time.

In most parts of the country children attend primary schools from 5 to 11. At 11 they transfer to all ability ('comprehensive') state schools. A small number of areas have 'middle schools' where the children transfer at 8 and 13. Most comprehensive schools take pupils from 11-18, although in some areas upper secondary pupils transfer to local tertiary colleges.

Historically, state schools have been run by local education authorities, of which there are 174 in England and Wales. In recent years schools have been encouraged to become 'academies', paid for centrally by the state and free of local authority control. This policy began under the last Labour government ostensibly as a way of turning around underperforming schools in deprived areas by injecting funds to give a fresh start. Since 2010, under the new Coalition government, this process has accelerated. The focus on underperforming schools has been dropped and all schools are being encouraged (in some cases required) to consider changing status. The objective is that the great majority of schools should opt out of local authority control. An important effect of this change has been to reduce the power of local authorities.

At the time of writing there are some 2,000 academies, mainly secondary schools, and the number is growing quickly. The government is also encouraging parent groups to set up so-called 'free schools', with government funding. As yet the numbers are small. What effects these changes will have are hotly debated. Where it is available, the evidence is often highly contested. One clear consequence has been the diminution or loss of the local authorities' ability to provide advice. In the field of STEM this advice has historically been important. We describe in Section 5 various initiatives that have been put in place to replace it.

Some 7% of pupils attend private ('independent') schools with the figure rising to around 18% for students over the age of 16. There are 164 selective ('Grammar') schools. The great majority of pupils in these schools come from higher socio-economic groups. While the numbers of students are small, the independent and grammar schools have a disproportionate effect on the higher echelons, especially in STEM.

3.1.3 The National Curriculum and national testing

Since 1988 schools in England, Wales and Northern Ireland have had a National Curriculum. There are some differences between the curricula in the three countries but they are not substantial. The National Curriculum is compulsory in state schools. Independent schools, the new academies and free schools are not required to follow the National Curriculum, but in practice most do. Academies must teach a broad and balanced curriculum including English, mathematics and science. In Scotland there is a recommended curriculum (Curriculum for Excellence) which is non-statutory.

Annex 1 summarises the structure of education by age, school year and curriculum stage. In essence the Curriculum is divided into four ‘Key Stages’ Primary education is in two stages; Key Stage 1 (Years 1 and 2) and Key Stage 2 (Years 3-6). Mathematics and science together take up some 20% of curriculum time and, along with English, constitute the ‘Core’ subjects, which are compulsory from 5-16. A range of other subjects, known as ‘Foundation’ subjects, are compulsory at one or more Key Stages. All pupils take national tests (often referred to erroneously as SATs (Standard Assessment Tests) at the end of Key Stage 2, that is, in Year 6. Initially pupils took national tests in all three Core subjects, but testing in science was discontinued in 2009. National testing has had a profound effect on education in the UK.

At Key Stage 3 (Years 7-9, age 11-14) all pupils follow a general curriculum. Mathematics and science are compulsory and typically take up 20% of teaching time. ICT and Design and Technology are also compulsory. Until 2008 pupils took national tests at the end of KS3 in English, mathematics and science.

At Key Stage 4 (Years 10-11, age 14-16) mathematics, science and ICT remain compulsory, but design and technology (D&T) is optional. Most students study for national exams known as GCSEs (General Certificate of Secondary Education). Students study for exams in a range of subjects, typically 8-12 for higher attaining students, fewer for lower attaining students. GCSEs are graded from A*-G. Normally 5 GCSEs at C or better are the minimum requirement for further academic study and schools are rated by the percentage of their students who achieve 5 A*-Cs, including mathematics and English. The ratings for all schools are published in the local and national media.

This target has become a very important driver, both for individual students and for schools and we discuss its effects below. Nationally around 55% of students achieve the target. School performance ranges from 100% to below 15% of pupils achieving the target. Results are strongly influenced by socioeconomic status.

In 2011 the government introduced a new target, the EBacc, which requires that three of the five subjects should be English, mathematics and science. This is not at the moment a qualification in itself, but a school performance measure. The numbers achieving the EBacc are significantly lower than those achieving the target of 5 GCSEs. The content of the EBacc is the subject of debate with strong lobbying from representatives of the arts and humanities particularly vociferous. Early in 2013, the government announced that science could include biology, chemistry, physics and computer science.

In 2012, the government announced further plans to introduce a new suite of qualifications replacing GCSEs in core academic subjects, to be called English Baccalaureate Certificates (EBCs). Initially these would have been available in English, mathematics, the sciences, history, geography and languages. They would have become the only qualifications that counted towards achievement of the EBacc. In February 2013, the government announced that it had decided not to introduce EBCs although it would make changes to the existing GCSE examinations.

At the moment schools may choose between the GCSE examinations offered by three awarding bodies. With the introduction of EBCs this would have changed and there would have been only one examination for each subject, offered nationally. Again, in February, this policy was reversed. At the same time, draft curricula for English, mathematics and science for Key Stage 4 (age 14-16) were published.

3.1.4 Upper secondary education (‘post-16’)

After GCSE, the more academic students (some 50% of the cohort) stay on at school or college for another 2 years and study for GCE (General Certificate of Education) Advanced level ('A levels'). This period of study is in two stages, AS (Advanced Supplementary) in the first year followed by A2 in the second, to give a full A level. Students may stop after one year to gain an AS, worth in effect half of a full A level. Students typically take 4 AS levels in year 12. After a year they drop one of these, depending on their exam results, and continue to study three subjects at A2 level, giving three full A levels, which is the normal university entrance requirement. A and AS level passes are graded A*-E.

Recently, however, the government has announced that AS levels will only be taken as standalone, one-year courses and that A levels will be examined only at the end of the two-year course. This move has been widely criticised not least by Cambridge University's Admissions Director on the grounds that the AS results are the most reliable indicator available of an applicant's potential to thrive.

Most schools will offer a menu of 10-15 subjects at A level. Larger schools and colleges are able to offer more choice than smaller ones. Students tend to specialise either on the science or the arts/humanities side. This is not compulsory, although it tends to be recommended, and choice is often affected by timetabling constraints. A level classes are nearly always taught by specialists.

Of the remaining students the majority go on to some form of vocational education or training, possibly linked to employment; some go directly to employment. Around 5% of the age cohort become NEET (not in education or training).

3.1.5 Teachers

Teaching in the UK is a graduate profession. The completion of a course of Initial Teacher Training is necessary in order to attain Qualified Teacher Status. The number of routes into teaching have increased in recent years with increasing emphasis on what are termed 'school-based' (as opposed to 'university-based') schemes. One-year postgraduate courses, which have provided the majority of trained secondary teachers are becoming more common at the primary level. Bursaries are available for trainee teachers in a number of shortage subjects including mathematics and the sciences.
All state-funded schools timetable five non-teaching days each year which may be used for staff development (In-service Education and Training or INSET). CPD (Continuing Professional Development) is not mandatory. Access to CPD appears to have declined in recent years although the data are not robust.

3.1.6 Higher education (HE)

The higher education system has expanded greatly over the past twenty years. The growth has been both in the number and the size of universities. There are now some 130 universities (i.e. bodies that award degrees) in the UK. All but a couple are public bodies. Most universities claim to do research as well as teaching, but in practice, research is highly concentrated. In 2010/11 around 75% of UK university research funding went to the 24 larger and older universities, known as the Russell Group.

The UK has historically had low levels of participation in higher education (compared with, for example, the USA). In the late 1990s, the then New Labour government set a target that 50% of young people should go to university. What this meant was never precisely defined and it was in truth more of an aspiration than a target. Nevertheless the numbers of students going on to higher education has risen sharply, to the point where around 30% of men and 40% of women in each year group in the UK leave with degrees. However while the numbers in the UK have risen, the numbers in other industrial nations have been rising faster and the UK fell from third to fifteenth in the international league of graduate numbers between 2000 and 2008, according to OECD figures. See http://www.bbc.co.uk/news/education-11438140. The expansion of the universities has been one of the major factors in the changing picture of STEM education in the UK and we return to this question below.

Entry to HE depends on A level results. The minimum requirement is two A level passes. Elite universities typically ask for BBB or better.

This growth of higher education has been not been centrally coordinated and has put strains on other parts of the system. In particular, A levels, which have been around since the 1950s, were designed as a matriculation system for an elite, when around 5% of students went to university. Numbers taking them have grown hugely and pass rates have increased steadily. This has led to persistent questioning of the standard of A levels.

The A level system means that many students study a narrow curriculum from an early age. This has important consequences. For example, a student wanting to study science at an elite university is likely to have to focus entirely on sciences and mathematics from the age of 16. Conversely most students outside the sciences do no mathematics after 16 and levels of participation in mathematics in the UK (except Scotland) are well below international norms. We discuss this issue below (Section 3.3).

Nevertheless, A levels are a fundamental feature of UK education and despite regular debate no government has seriously tried to introduce alternatives. There are two key reasons. The first is that politically it would be very difficult. Broadening the upper secondary curriculum would inevitably mean less depth of study, opening government to accusations of 'dumbing down'. The second is that the advanced level of study, (equivalent to 1st year undergraduate study in many countries) means that UK universities can offer three-year degrees. The cost implications of moving to a broader upper secondary curriculum are obvious. Scotland has a different system in which students study a broader curriculum of six 'Highers', but degrees in Scottish Universities take four years.

The financing of universities has also been undergoing profound changes. Until 1998 university education was essentially free to home students, paid for through central government grants to universities. Universities did not charge fees, and grants were available to support living costs. In 1998, fees were introduced, at the relatively low level of £1,200 pa. Alongside this a loan system was introduced. Students pay back their loans via the taxation system once they are earning a threshold amount. Fees were subsequently increased to £3,000 pa and in 2010 the Browne Review, commissioned by the Labour government, recommended that universities be allowed to charge what fees they wished, to a maximum of £9,000 pa. The objective was to introduce a market into higher education but in practice almost all universities decided to charge the maximum of £9,000 pa. Universities must use some of their fee income to offer bursaries to poorer students.

This policy was implemented in 2012/13. The long-term effects of the increased costs of higher education for students are unknown. The numbers of students applying for places appears to have declined, but there are different possible reasons for this, not least the current recession.

The effects on STEM are unknown. In addition to the fee income, the government makes a direct grant to universities to recognise the extra cost of certain kinds of education. STEM courses attract higher levels of support. In theory the new regime could offer opportunities to attract students into STEM subjects (by offering bursaries and/or reduced fees). It is too early to say whether this will happen.

An important by product of these changes is that overseas students (that is, not Home or EU students), who pay substantially larger fees, have become financially very important to universities and many institutions are actively marketing themselves, especially in Asia.

Taught Masters courses have become an important growth area for universities in recent years although funding for such courses is the subject of concern among the elite universities.

3.2 International comparisons and the UK education system

According to a recent analysis of educations systems, the UK is ranked sixth best in the world (Pearson 2012). The UK's higher education system was ranked 10th (out of 48) in the 2012 *Universitas 21* assessment based on resources, environment, connectivity and output (Universitas 2012). However, an analysis of international comparisons of student attainment suggests that the UK has a relatively long tail compared with many other developed countries. That is, the gap between the highest attaining and the lowest is greater than might be expected of an education system that has undergone significant and prolonged change.

As in most countries, politicians and the media in the UK are intensely interested in the results of international comparisons, especially PISA and TIMSS. The headline numbers from the most recent PISA study apparently show that between the 2000 and the 2009 series of tests the UK slipped from 8th position to 27th in mathematics and from 4th to 16th in science (DfE, 2011). These numbers have been seized on by the press and by government politicians as evidence that standards in the UK have declined alarmingly and that radical action is needed. Within the educational world there are well-known arguments to suggest that these numbers are not nearly as dramatic as they appear. The OECD and others have criticised the government for what they see as misuse of the data (Full Fact, 2010).

For all this it is accepted that the UK's position has declined relative to other countries, and especially relative to the Pacific Rim countries (Korea, Singapore, Hong Kong, etc.) which perform consistently well. To what extent this matters is another question. The high-performing countries have their own concerns, (for example about the extent to which their students are able to think creatively). There is also a concern that politicians (of all parties) have a tendency to look at the higher performing countries and see only the features that are consistent with their own views of how things ought to be. This kind of cherry picking rarely produces positive results, not least because cultures and wider educational systems vary so hugely. (See for example Askew et al., 2010 for a nuanced discussion of this issue).

3.3 The uptake of STEM in education

3.3.1 Schools – Primary and lower secondary

Mathematics and science are compulsory for all pupils until the age of 16. As for all national curriculum subjects, attainment is measured against a set of eight levels. Descriptors which set out what a pupil operating at each level should know, understand

and be able to do are published for each of the attainment targets. The expectation is that most pupils will progress by approximately one level every two years so that by the end of Key Stage they are expected to achieve Level 5 or Level 6.

At the end of primary school (Key Stage 2) pupils take national tests in mathematics and English. The target is level 4. National testing in science was stopped in 2008.

In 2012 84% of pupils in England achieved the target in mathematics in the national tests (compared with 85% in the Teacher Assessments). There was no difference in performance between boys and girls. In the Teacher Assessment of pupils' science attainment, 87% achieved the target (up 2 percentage points from 2011). In mathematics, 39% of pupils achieved Level 5 or above, with boys outperforming girls (42% c/w 36%). In 2012 Level 6 tests were introduced and were passed by 3% of pupils. Again boys outperformed girls (4% c/w 2%).

Performance in mathematics has improved markedly over the past fifteen years. In 1998, only 59% of pupils achieved level 4. That number rose to 72% by 2000 and has been rising steadily but more slowly ever since. (However note that what is meant by Level 4 has changed; when the idea of National Curriculum levels was first introduced they were intended to be a measure of what the average pupil might be expected to achieve. They have since become targets).

The causes are debated, but it seems likely that the large gains in the early years were linked to the introduction of the National Numeracy Strategy in the late 1990s. The strategy for English had a similarly large effect. The secondary strategies which followed seem to have been less effective.

There are some 200,000 primary teachers. Very few of these are graduates in mathematics or mathematically demanding subjects such as physics or engineering. Having said that, the numbers of graduates in any one subject is not high given the number of subjects in the primary curriculum. In 2008 the government asked Sir Peter Williams to conduct a review of mathematics teaching in primary schools. He recommended that the DfE should develop a funded training programme to place a mathematics specialist in every primary school within ten years. This recommendation was adopted. The minimum level of mathematics needed to become a primary teacher is a GCSE grade C. Williams considered whether this should be raised, but concluded it had to be left as it is for the time being.

At Key Stage 3 (Years 7-9, that is, 11- 13 year olds) pupils study general science, although the curriculum is divided into the three main disciplines. There are four main strands (with assessment criteria specified in four attainment targets) including three that focus on the content of science: Organisms, their behaviour and the environment; Materials, their properties and the earth; Energy, forces and space. These correspond broadly to biology, chemistry and physics. Some earth science appears in all three strands. A fourth strand, 'How science works', is taught across all three strands and is intended to introduce pupils to the processes and methods of science.

In mathematics there are also four attainment targets: Using and applying mathematics; Number and algebra; Shape and space; and, Handling data.

In science pupils are, for the most part, taught by subject specialists, although shortages in some subjects, particularly physics, mean that teaching by non-specialists (i.e. teachers who are science graduates, but not discipline specialists) is not uncommon.

Around three quarters of those teaching mathematics in secondary schools have a degree or higher in a ‘relevant subject’ (broadly speaking mathematics, physics or engineering). The proportion of appropriately qualified teachers rises with the age of the pupils and at upper secondary level nearly all teaching is by mathematics or equivalent graduates.

3.3.2 Schools – GCSE

At Key Stage 4, science taught as a ‘double subject’ – i.e. it is equivalent in value to two GCSEs and takes up about 20% of teaching time. Physics, chemistry and biology are usually taught separately, although the curriculum is coordinated. Pupils are mainly taught by subject specialists, although a shortage of physics teachers in particular mean this is not always possible.

‘Triple Science’, is an option in which pupils take three separate GCSEs, in physics, chemistry and biology. Normally only offered to higher attaining pupils, it is an option that has grown quickly in recent years, with strong government backing. We discuss this policy and its effects below.

Applied science is third option that has also grown in recent years. It is generally taken by lower attaining pupils. Applied science struggled to gain acceptance from teachers, parents and employers and the numbers entered each year have been relatively small (Bell and Donnelly, 2007). As Bell and Donnelly point out, ‘The relentless association of the word ‘vocational’ with lower status, and with training for narrow and sub-professional employment is of course a key issue here’ (2007, p. 8).
Mathematics is a single subject although a double subject GCSE (in effect a linked pair of ‘pure’ and ‘applied’ mathematics) is being piloted in several hundred schools. Pupils may take a full (‘Higher’) GCSE, or a ‘Foundation’ GCSE for which the maximum grade they can achieve is a C. Pupils taking the ‘Foundation’ exam would not cover the full syllabus. In February 2013, the government announced plans to remove the possibility of taking a Foundation GCSE in any subject.

A recent report from the National Audit Office (2010) has summarised the data about trends in take-up and achievement. This is both a concise and authoritative account and we reproduce it here in full:

> **Take-up and achievement at Key Stage 4 (14-16 years)**
> Take-up
> 2.2 In 2006, a new GCSE science curriculum was introduced in place of ‘Double Science’, where pupils had received two identical grades for a course with double the regular coursework. Pupils may now take the renamed Core Science, plus one of two new complementary courses: the academic-focused Additional Science, or Additional Applied Science, which is vocationally focused. Pupils receive two individual grades. Most pupils follow this route, but a growing minority study for examinations in separate sciences, primarily biology, chemistry and physics.
> **2.3 Figure 3** lists the main science subjects available at GCSE, with the total number of entries each year between 2001-02 and 2009-10. Adjusting the figures to acknowledge year-on-year changes in the number of young people aged 15-16, the figures show a decline in the proportion of pupils studying GCSE science between 2001-02 and 2005-06, followed by signs of recovery from 2005-06 to 2009-10. Take-up of the separate sciences grew by almost 150 per cent between 2004-05 and 2009-10.

Figure 3
Trends in GCSE entries in England, 2001-02 to 2009-10

Subject	2001-02 (000s)	2002-03 (000s)	2003-04 (000s)	2004-05 (000s)	2005-06 (000s)	2006-07 (000s)	2007-08 (000s)	2008-09 (000s)	2009-10 (000s)
Single Science	51.8	53.0	55.0	65.5	71.3	67.8			
Double Science	466.3	474.5	479.6	450.9	443.0	434.8			
(counts as two GCSEs)	466.3	474.5	479.6	450.9	443.0	434.8			
Core Science							491.6	456.0	404.9
Additional Science							354.5	324.3	288.5
Additional Applied Science							51.2	47.4	38.5
Biology	40.5	42.6	44.8	48.3	51.8	54.2	74.7	88.0	115.7
Chemistry	39.1	40.9	43.1	45.9	49.2	51.1	68.3	83.1	113.1
Physics	38.6	40.1	42.5	45.4	48.8	50.7	67.3	82.3	112.1
Other sciences	2.8	2.7	2.7	7.7	3.3	15.3	4.9	23.8	21.7
Total science entries	**1,105.4**	**1,128.3**	**1,147.3**	**1,114.6**	**1,110.4**	**1,108.7**	**1,112.5**	**1,104.9**	**1,094.5**
Population aged 15	636.3	655.8	649.7	656.6	667.3	656.6	636.2	628.7	612.1
Total science entries per head of population aged 15	**1.74**	**1.72**	**1.77**	**1.70**	**1.66**	**1.69**	**1.75**	**1.76**	**1.79**

NOTES
1 Single Science entailed a less extensive curriculum and counted as one GCSE.
2 Double Science counted as two GCSEs, hence two sets of figures are shown and counted above.
3 Core and Additional Science / Additional Applied Science replaced Single and Double Science from 2007-08.
4 Maths entry figures are not shown since maths is compulsory at GCSE.
5 2005-06 to 2008-09 entry figures are 'revised', and 2009-10 figures 'provisional'. 2010 population figures are not yet available, hence the 2009 figure for 14-year-olds has been used to estimate the 2010 figure for 15-year-olds.

Source: National Audit Office analysis of Statistical First Releases and Office for National Statistics mid-year population estimates

Achievement at GCSE

2.4 Figure 4 shows generally rising trends in GCSE achievement in maths and science, including separate sciences, where the improvements were achieved at the same time as increased take-up.

Figure 4
Percentage of GCSE entries in England achieving A*-C

Subject	2001-02 (%)	2002-03 (%)	2003-04 (%)	2004-05 (%)	2005-06 (%)	2006-07 (%)	2007-08 (%)	2008-09 (%)	2009-10 (%)
Single Science	18	16	17	20	20	18			
Double Science	52	53	54	57	57	58			
Core Science							59	61	61
Additional Science							68	67	68
Additional Applied Science							31	34	35
Biology	91	89	90	90	90	90	91	93	94
Chemistry	90	90	90	91	91	92	95	95	94
Physics	90	90	91	91	91	92	94	94	94
Mathematics	52	51	53	55	56	57	59	61	65

NOTE
1 2005-06 to 2008-09 figures are 'revised', and 2009-10 figures 'provisional'.

Source: Statistical First Releases

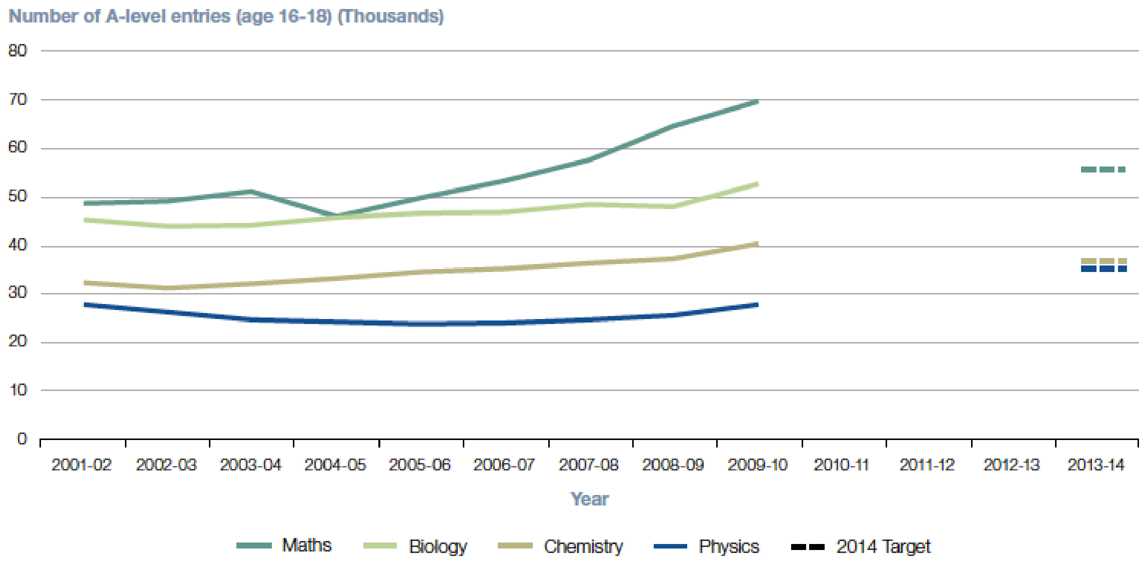
3.3.3 Schools – upper secondary

Physics, chemistry and biology are overwhelmingly the most popular science subjects. Mathematics is a single subject, although there options are available, typically in statistics, mechanics or decision mathematics.

We again draw on the NAO's report on trends in take-up and achievement:

> Take-up at A-level
> 2.7 In 2005-06, the then Government set a target to achieve year-on-year increases in the number of people taking A-levels in physics, chemistry and maths, so that by 2014 entries to physics would be 35,000 (24,200 at the time), to chemistry 37,000 (33,300 at the time), and to maths 56,000 (46,168 at the time).10 Although no equivalent was set for biology, the Department has had an internal target to maintain numbers of entries from one year to the next.
> **2.8 Figure 6** shows trends in A-level entries in maths and science subjects between 2001-02 and 2009-10. During that period, entries for maths increased to over 10,000 above the original 56,000 target, which the Department has since raised to 80,000. Entries for chemistry also exceeded the 2014 target in 2008-09. Physics entries, while increasing slightly since 2005-06, are currently at only 79 per cent of the 2014 target level. Biology entries have increased by 16 per cent since 2001 – 02.

Figure 6
Numbers of A-level entries in maths, physics, chemistry and biology, 2001-02 to 2009-10



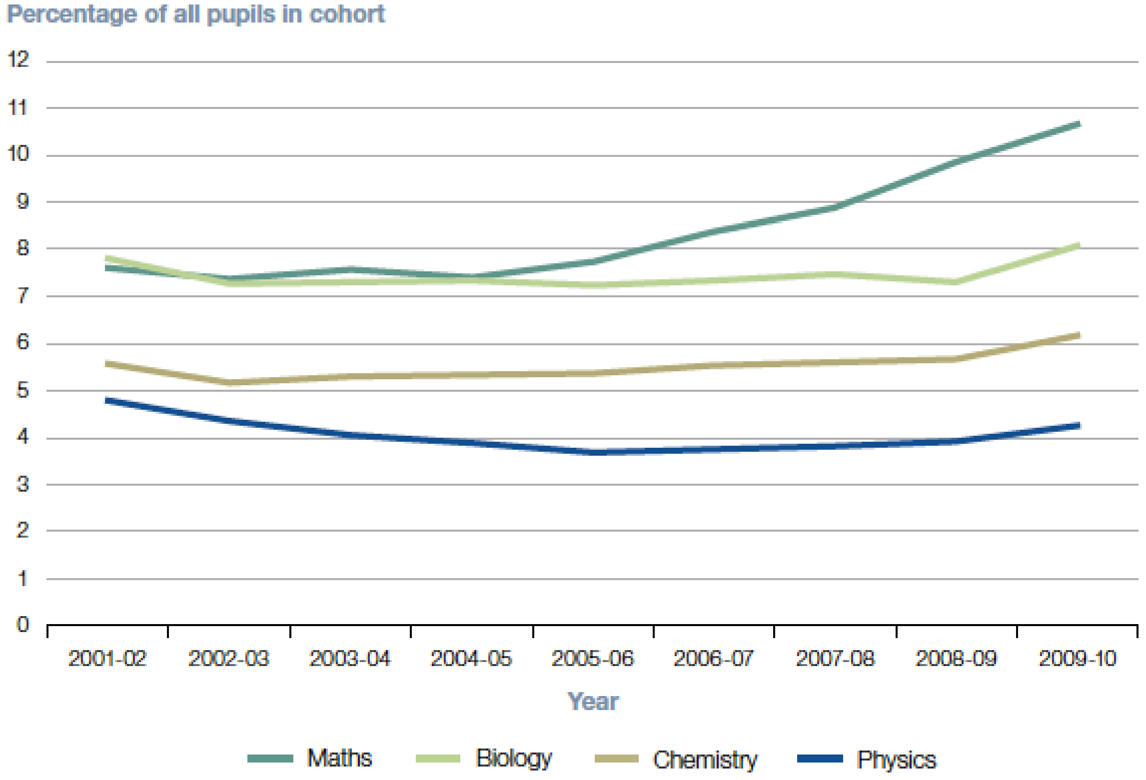
NOTE
1 2009 figures are 'revised', and 2010 'provisional'.

Source: Statistical First Releases

> **2.9 Figure 7** shows that take-up of A-level maths, chemistry and physics has increased not just in absolute numbers, but also as a proportion of all young people in the relevant age group. Since 2004-05 (the first year covered by the *Science and Innovation Investment Framework*), the proportion of young people choosing maths has increased by over three percentage points. Chemistry has increased by 0.9 percentage points, while physics has increased by only 0.4 percentage points, and remains slightly below its 2002 – 03 level.

Figure 7

Percentage of former GCSE cohort entering A-levels in maths, physics, chemistry and biology, 2001-02 to 2009-10



NOTE

1 2009 figures are 'revised', and 2010 'provisional'.

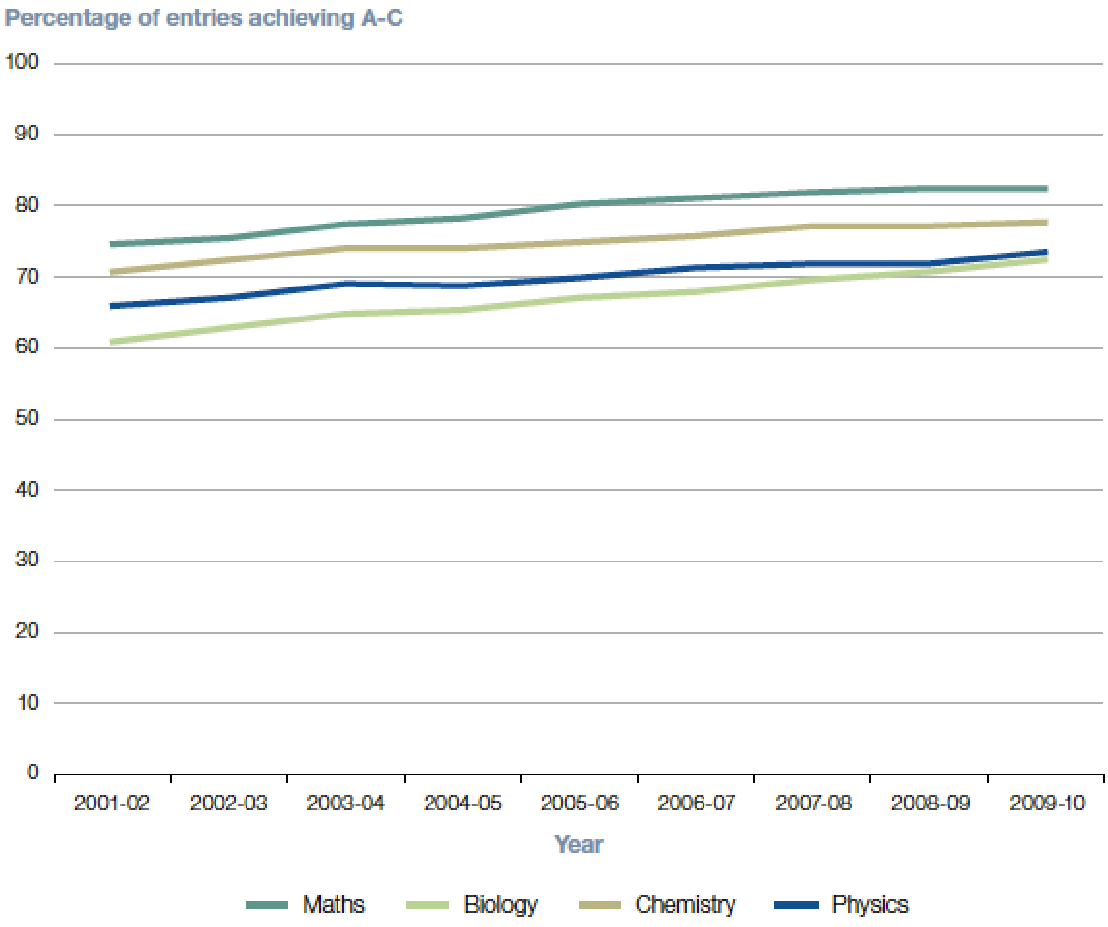
Source: Department for Education

Achievement at A-level

2.10 The proportions of entrants achieving grades A-C in A-level maths, biology, chemistry and physics increased between 2001-02 and 2009-10, with maths rising from 74 to 82 per cent, biology from 61 to 72 per cent, chemistry from 71 to 78 per cent and physics from 66 to 74 per cent. (Figure 8)

Figure 8

Percentage of entries to A-level maths, physics, chemistry and biology achieving grades A-C, 2001-02 to 2009-10



NOTE

1 2009 figures are 'revised', and 2010 'provisional'.

Source: National Audit Office analysis of Statistical First Releases

The uptake of A level mathematics has had a complex history. The numbers had been declining slowly but steadily for about ten years until 2000 when there was a sharp decline of some 20%, consequent on a major change to the A level system ('Curriculum 2000'). In 2002 the number reached a low of 54,000. Since then numbers have been rising steadily. They are now greater than they were twenty years ago and they continue to rise. However this is against a 30% increase in A level entries in all subjects, so mathematics is still below its peak in relative terms.

There is a further mathematics A level which is taken by some 15,000 students. Here too numbers have grown substantially in recent years. A government-funded initiative run by the not-for-profit organisation MEI (Mathematics for Education and Industry) has led to the numbers taking A level in further mathematics rising from a fairly static 5,000 up to 2005 to 12,000 in 2010. An important driver has been a national network of Further Mathematics Centres, which support schools through distance learning and mentoring.

A level mathematics has as its core objective the preparation of students for higher education courses in mathematics, physics and engineering. A further 20,000 students take AS but do not go on to a full A level. Most of the students taking A level have a grade A or better at GCSE. Only around 5% of B grade students go on to A level and almost none with grade C. This contrasts with the situation in other A level subjects.

For students who do not take A levels there is little else on offer. Some students will continue with more advanced mathematics as part of a technical vocational course but numbers are small. There are a number of students who re-sit their GCSE because they have not achieved a grade C. The outcomes are poor and many do not improve. Some students will take mathematics (often called Functional mathematics) as part of their vocational course, but the intention is often remedial and levels are typically low. The focus will be mainly on numeracy.

Overall fewer than 20% of students continue with mathematics after the age of 16. This is exceptionally low by international standards. In a recent study of 24 OECD countries no country outside England, Wales and Northern Ireland had a participation rate lower than 50% and most had participation rates of 75% or better.

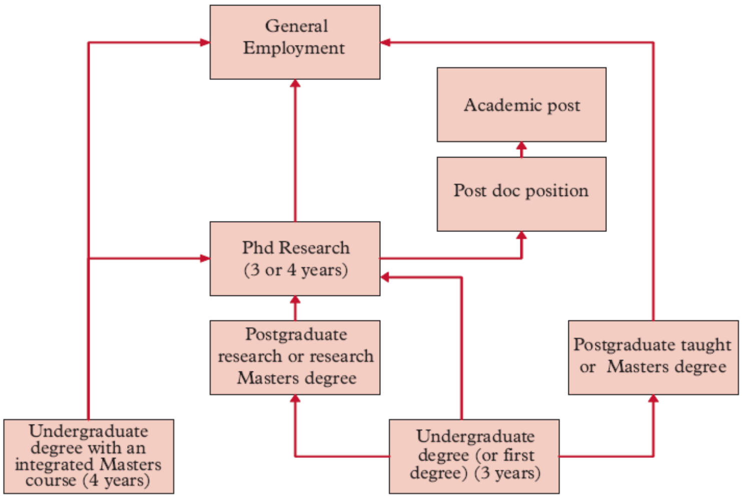
In short, there is an important bifurcation at the age of 16. A significant number of students, around 15% of the cohort, continue with relatively advanced courses of study. A few do essentially remedial courses. The great majority do no mathematics at all. This is (at last) being recognised as a serious problem and upper secondary (post 16) mathematics is one of the most active policy areas at the moment.

3.3.4 Higher education

In July 2012, the House of Lords Select Committee on Science and Technology published a report on Higher Education in Science, Technology, Engineering and Mathematics (STEM) subjects (House of Lords, 2012). We know of no more authoritative or up to date picture of the situation, so we reproduce here in full the relevant section of its report.

> QUALIFICATIONS IN HIGHER EDUCATION
> 58. There are a number of qualifications which students can gain in HE. In general, they are classified as either undergraduate (first) and postgraduate (higher) degrees (see Figure 2). First degrees have, in the past, usually lasted three years and resulted in a Bachelors degree. There has, however, been a move towards four year courses in STEM subjects, particularly engineering, leading to an integrated Masters degree and increasingly Masters are seen as a prerequisite for postgraduate study internationally.[72] Such a degree, or its equivalent at Masters level, is essential to achieving Chartered status in engineering and some other areas.
>
> 59. After completing a first degree, graduates have the option of continuing their education either through a taught Masters degree or through research. A research Masters degree usually takes a year, after which a student may progress to a doctorate (PhD); alternatively, a student may go directly to studying for a PhD. A PhD may take three to four years. In HESA data, these two routes are classified as ‘postgraduate research courses’. Taught Masters are classified by HESA as ‘postgraduate taught courses’. The purpose of a taught Masters degree is said to be threefold: to specialise in a specific subject or area, to convert from an expertise in one discipline to a degree in a second discipline, or to enhance a Bachelors degree to qualify for a ‘license to practice’ in an area such as engineering. Doctoral graduates may chose to enter general employment or take a post-doctoral position with a view to pursuing a career in academia.

FIGURE 2
Qualifications in higher education



TRENDS

60. The overall number of 'qualifiers' (that is, students who have qualified for their award (graduates)) in STEM subjects at undergraduate level in HE has increased from approximately 118,000 in 2002-03 to over 140,000 in 2009-10; although, as a percentage of the overall number of HE students, the number decreased slightly from just over 43% in 2002-03 to just under 42% in 2009-10 (see Figure 3). These figures are based on a broad definition of STEM subjects (see Chapter 3). To achieve a better understanding of the growth in the uptake of STEM subjects, it is necessary to disaggregate them (see, as an example of disaggregation, Figure 4).

FIGURE 3
STEM qualifiers (UK and overseas) from HEIs[73]

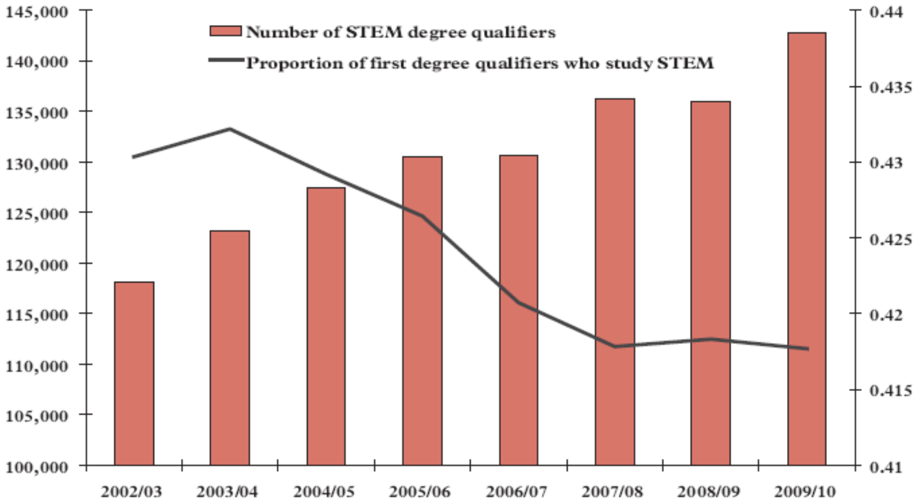
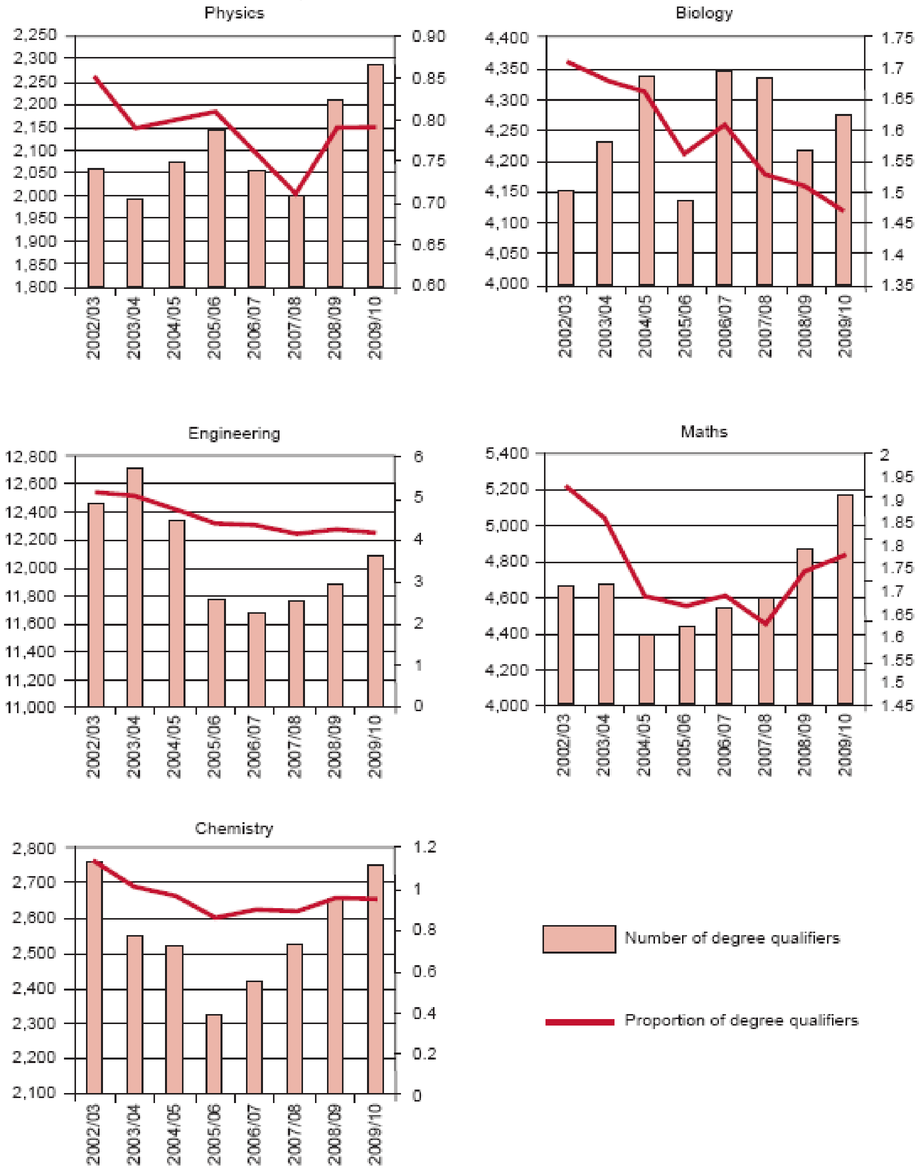


FIGURE 4
Number and proportion of UK domiciled qualifiers of some STEM subjects



61. Data in Table 2 set out in Appendix 6* to this report reveal a decrease or no growth in the number of UK domiciled first degree qualifiers in engineering (-3%) and chemistry (0%) over an eight-year period, from 2002-03 to 2009-10. This is in contrast to an increase in qualifiers for all subjects of 20%. In particular, the number of students studying computer science has dropped by 27%. On a more positive note, there has been an increase in the number of mathematical sciences qualifiers of 11% over the period and a similar 11% increase in physics. This is a turnaround from the previous decade when there was a significant drop in the number of students studying these 'core' STEM subjects from 1995 to 2000.[74] However, this increase is from a low starting point and each subject still represents a very low proportion of the overall STEM figure (with only 2,290 students acquiring a first degree in physics and 5,175 in maths out of the total of 122,940 studying STEM subjects in 2009-10). We note that there have been very large increases in student qualifiers in sport science, which make up a significant proportion of the number studying biological sciences (up 122%, from 3,650 to 8,120) and forensic and archaeological science (up 349%, from 360 to 1,615) over the same period.

62. The number of UK domiciled STEM Masters degree qualifiers has risen by 30% over the same eight-year period (see Table 4). This is in contrast to a 34% increase in the number for non-STEM subjects. There has also been a significant decline in the number of qualifiers in computer science (-45%) and chemistry (-12%) with little growth in the mathematical sciences (2%). Engineering increased by 37% and physics by 43%. Again, there have been very large increases in the number of qualifiers in sports science (172%) and forensic and archaeological science (94%). This data relates to UK domiciled qualifiers only. The trends look very different when taking into account EU and overseas students (see Chapter 6).
63. Table 6 shows increases in the number of UK domiciled PhD qualifiers across the board, with a 15% increase in STEM subjects and 15% increase in non-STEM subjects between 2002-03 to 2009-10. There are some areas of concern. PhD degree qualifiers in chemistry, for example, decreased by 11% while biology qualifiers decreased by 16%. There was also little growth within engineering (3%).

64. Historical data on the trends in student numbers in STEM reveal that overall there has been an increase in the number of STEM students, although a significant proportion of that growth has taken place in what the Government describe as the 'softer sciences', such as sports science and forensic science. There has been relatively little growth in traditional or 'core' sciences, such as engineering and a decline in computer science.
* Attached as Annex 2 to this report.

Section 4. Access of STEM graduates to labour markets in the UK

4.1 Introduction

Concerns over the availability of STEM graduates, their role in the labour market and the potential for STEM professionals to galvanise the economy have been established over a long period of time in the UK (see for example Dearing, 1997; House of Lords, 2012; Robbins, 1963; Roberts, 2002; Sainsbury, 2007). Concerns about a shortfall in the number and quality of science graduates and professional scientists have been raised by three main groups in the UK; by government, the science lobby (which includes organisations such as the Academy of Medical Scientists, the Royal Society, the Institute of Physics or the Campaign for Science and Engineering (Fjaestad, 2007)) and by academics. The main stakeholders from these groups are represented by the evidence published in the recent House of Lords report *Higher Education in Science, Technology, Engineering and Mathematics (STEM) subjects* (2012). While there are, as suggested above, a large number of reports about the access of STEM graduates to the labour markets, the House of Lord Select Committee (2012) report, mentioned several times above, is notably the most recent and comprehensive. As a result it reflects the tone for how such debates are currently framed by government and much of the science lobby, described below.

The key questions at the heart of policy debates about STEM graduates and their access to the labour markets concerns issues of quantity and quality. Are there enough STEM graduates to fulfil the needs of STEM employees - and thus to fuel the ability of the UK to compete in economic markets at the global scale - and are these STEM graduates 'good' enough for the purpose of working in STEM professions and driving the economic growth of the UK forwards (Department for Business Innovation and Skills, 2011; House of Lords, 2012). In the global recession, such discussions appear to have become more pressing for UK policy makers and the science lobby. Indeed, in a speech from 2009, Gordon Brown is quoted as saying 'science would not be a victim of the recession' (Barrett & Wynarczyk, 2009, p. 210). Instead, STEM has been framed as a way out of the recession and as a result, of considerable importance to UK policy makers. As Greenwood *et al.* have argued in a report written for the Royal Academy of Engineering: 'Science, Technology, Engineering and Mathematics (STEM) are subject areas that are deemed crucial for a modern economy. Having a sufficient supply of skilled workers trained in these subjects is seen as a pressing policy priority' (2011, p. 3).

Research has explored the nature of STEM studies at higher education, the views of STEM students and graduates as well as the jobs STEM graduates move into. Aspects of this research suggest that if narrow definitions of what 'counts' as STEM were widened, a different picture might be painted, with more students studying STEM at university. In addition, there is a question about whether STEM graduates might have useful and valuable careers in 'non-STEM' jobs, and might be better understood as contributing to the economy rather than as having leaked from the STEM pipeline.

4.2 Government and science lobby views

The House of Lords (2012) report, *Higher Education in Science, Technology, Engineering and Mathematics (STEM) subjects,* explicitly links the need for an adequate supply of high quality STEM graduates to the UK labour markets to economic growth and prosperity. The report quotes from evidence provided by the Council for Industry and Higher Education (CIHE) that warns;

> the workforce of the future will increasingly require higher-level skills as structural adjustments in the economy force businesses to move up the value chain. These jobs of the future will increasingly require people with the capabilities that a STEM qualification provides. (House of Lords, 2012, p. 9).

Notably at different stages in the report there is a tension between whether an increase in STEM graduates would benefit the economy *regardless* of whether they went into a STEM career or not. The CIHE evidence suggests that STEM graduates and their skills are a valuable resource above and beyond the needs of the STEM labour market. The House of Lords (2012) report is more even handed than other government or science lobby reports in its treatment of how STEM graduates access to the labour markets is framed. Indeed, the report, drawing on evidence from business and industry as well as the science lobby and higher education providers, concluded insufficient evidence was available about the supply and demand of STEM graduates and suggested that a specific body be charged with carrying out such research.

The House of Lords (2012) report highlighted in particular the inadequate supply of mathematics students at both A level and undergraduate level. However, it is worth noting that the report was less clear about whether or not there was an insufficient supply of all STEM graduates. Instead, the report questioned whether STEM graduates were adequately prepared through education for STEM employment. The questions the report concludes with focus therefore on whether quantity or quality is at stake with the issue of STEM graduates and the labour markets. In particular, the report raised questions about the quality and provision of careers advice available to STEM students. For instance, the report questions how remarkably few STEM students appear to receive careers advice about the kinds of work studying STEM subjects could lead to. This is an established concern for those invested in the STEM aspects of British labour markets and the quality of STEM careers advice has been critiqued elsewhere (Woodley & Brennan, 2000). Less clear, is whether improved careers advice would influence more students to pursue STEM related careers.

The Confederation of British Industry (CBI) published two reports in 2011 (*Building for Growth: Business Priorities for Education and Skills* and *Mapping the Route to Growth*) with a stronger emphasis on the need for STEM graduates for future STEM jobs. The reports argued more STEM graduates were needed to meet the needs of STEM employers and develop the British economy. For example, *Building for Growth: Business Priorities for Education and Skills* states that 'STEM skills shortages are widespread – 43% of employers currently have difficulty recruiting staff, rising to more than half of employers (52%) expecting difficulty in the next three years' (Confederation for British Industry, 2011a, p. 7). This report goes on to argue that both the quantity and quality of STEM graduates are key to the future growth of the UK economy. The report *Mapping the route to growth* suggests that as many as 80% of emerging jobs require highly skilled, STEM graduates (Confederation for British Industry, 2011b). To meet these anticipated needs the CBI argued a 40% increase in the numbers of STEM graduates would be required. Thus from the perspective of these representatives of British industry, there is a strong demand for more STEM graduates, not only to meet the perceived needs of employers at present, but to meet the predicted needs of British industry. This view is support elsewhere, for example in the Sainsbury (2007) report commissioned by government, which strongly links studying STEM subjects and STEM labour forces to innovation, and thus, to a stronger economy.

On a more individual level, research from the Institute of Education, sponsored by the Royal Academy of Engineering suggests that employers are willing to pay a premium for STEM graduates (Greenwood et al., 2011). Thus, not only will more STEM graduates and the growth in STEM industries support the economy of the UK on a national scale, individuals involved in such work may also benefit from higher salaries. Graduates with STEM qualifications not only earn more in their entry level jobs, but those who are employed in STEM occupations earn 19% more than those who are not employed in STEM occupations. This pattern is backed up by research from the CBI that suggested 41% of employers favoured STEM graduates and were willing to pay them more accordingly (Confederation for British Industry, 2011a).

The future needs for STEM graduates in UK labour markets have been benchmarked more cautiously by Wilson (2009) in a report for the CIHE. Wilson's report suggested STEM graduates with qualifications from NQF level 4 (beyond A level) and above were slightly more likely to be employed than other graduates in 2007, but that the difference was minimal. In terms of future projections, Wilson's report suggested there could be significant demand for those qualified to a high level in STEM subjects, while those with fewer or no qualifications will see little demand from employers. Thus, these reports on the demand for STEM graduates suggest a rising demand over time in the UK, based on current data.

Overall therefore, research from government, business and the science lobby suggests there is a need for more STEM graduates, and that financial rewards are in place for STEM graduates entering the labour markets, particularly those entering STEM employment. The conditions appear to be in place for STEM graduates to gain employment in STEM fields. The report *STEM graduates in non-STEM jobs* (2011) from the Department for Business, Innovation and Skills (BIS) raises, therefore, a seemingly contradictory issue; why were STEM graduates not employed in fields related to their training?

The BIS report concludes that STEM graduates most likely to 'drift away from STEM' (2011, p.11) were those who were undecided about career options during their final year at university. Notably, the report found the majority of STEM graduates did not use their STEM specific degree knowledge at work, whether they were or were not in a STEM related job. For example, only 16% of STEM graduates interviewed for the BIS study believed they used their STEM skills a lot at work. Furthermore, STEM graduates appeared to be working in a range of occupations across STEM and non-STEM related employment. In contrast, however, 90% of STEM graduates interviewed felt they used general skills learned through their degree in their work. For employees, the broad skills of STEM graduates, such as numeracy and analytic skills were perceived as more appealing than specialist subject knowledge, however, STEM graduates were also seen to be less competitive in a commercial environment and to sometimes lack skills in team work, communication and organisation. From both employees and employers, STEM employment was not seen as more profitable, indeed, higher salaries were perceived to be linked to non-STEM careers by many. In other words, students at the top of their STEM subject at university were as likely to go into more profitable, high status careers such as those in law or finance. Overall, the BIS (2011) report concluded that the linear and simple view of supply and demand for STEM graduates was not reflected in the complexity of the employment decisions made by STEM graduates and employers, with many factors involved in career decisions. Thus the linear trajectory from STEM student to STEM professional is far from self-evident.

4.3 A counter-narrative about STEM recruitment and employment: academic research

Research conducted by Emma Smith and Steven Gorard in the UK has explored in whether prevailing rhetoric from government and the science lobby is justified in presenting the recruitment of STEM students as a cause for concern. Their work covers many of the issues involved in concerns over STEM recruitment, including the numbers of STEM students, the kinds of students who study STEM, the role of STEM recruitment initiatives and the first work destinations of STEM graduates (See, Gorard, & Torgerson, 2012; Smith, 2010; Smith & Cooke, 2011; Smith & Gorard, 2011).

Smith (2010) suggests two key issues in patterns of STEM students in Higher Education. Firstly, that there has been a shift in the kinds of science subjects studied, with a move towards a wider range of science subjects. For example, Smith (2010) suggests in terms of numbers, more students than ever before in the UK study Sport Science, Pharmacy, Medicine and Mathematics, while in contrast, the number of students studying engineering and physics has not increased.

Secondly, Smith's analysis suggests that initiatives designed to increase the numbers of students studying science have had little effect. In particular Smith (2010) concludes that the science education reforms of the last two decades in the UK, including the introduction of the National Curriculum and subsequent curriculum reforms, have made little difference to the numbers of students studying science at university, or, importantly, who those students are, with socio-economic, ethnic and gender patterns amongst STEM students in Higher Education remaining stable. There are two different questions here. Firstly, there is the question of 'who' pursues STEM subjects and employment and secondly, the question of the effectiveness of recruitment interventions.
In relation to the question of 'who' STEM recruits are, a second study published by Smith and Gorard (2011) highlighted the stratified nature of STEM graduates, in terms of socio-economic background, ethnicity and gender. They argued;

> While traditionally much of the literature in this field has focused on the experiences of female STEM entrants (for example Ceci *et al.*, 2009), research also points to the socio-cultural barriers faced by students from other non-traditional backgrounds (for example, Hurtado *et al*., 2009; Seymour and Hewitt, 1997; Wynarczyk and Hale, 2009; see also Gorard *et al.*, 2007). (Smith & Gorard, 2011, p. 161)

One key question, therefore in the UK context, is 'who' pursues STEM studies and STEM careers. Concerns about the diversity of STEM students and ultimately the STEM workforce have been raised elsewhere. The Royal Society of Chemistry and the IOP commissioned two reports that explored why minority ethnic groups were under-represented in chemistry and physics higher education courses (Elias, Jones, & McWhinne, 2006; Springate, Harland, Lord, & Wilkin, 2008).These reports concluded there was no on-size-fits-all solution and noted differences between students from different minority ethnic backgrounds. The reports found that physics at university was dominated by White, male students, while more minority ethnic students (excluding Black Caribbean students) study chemistry and pharmacy at university as compared to other subject.

As Smith and Gorard (2011) suggest in the quote above, attention to the representation of minority ethnic students and students from impoverished backgrounds in STEM subjects is comparatively new in the UK compared to the longer-standing focus on female students in STEM. While there have been few recruitment initiatives designed to encourage minority ethnic students to study and work in STEM, there is a longer history of initiatives focused on encouraging female students to pursue STEM subjects and careers.

In comparing targeted recruitment initiatives, Smith and Gorard (2011) conclude that there is little evidence to suggest they have made much difference. For instance they note that large numbers of female students continue to study biology while physics remains male dominated, despite investment in initiatives designed to balance this pattern. Similarly See, Gorard and Torgerson (2012) concluded, from their comparison of initiatives targeted at recruiting minority ethnic students to STEM, that of the evaluated projects they analysed, those which showed most promise involved significant extrinsic motivation, such as payment for studying STEM.

Furthermore, Smith and Gorard (2011) suggest, that despite considerable investment by recent UK governments in recruiting more STEM graduates, including the 'ring fencing' of funds for STEM courses in higher education, these initiatives have had little effect. Smith and Gorard's analysis of the notion of supply and demand for STEM graduates. Their analysis suggests that the number of STEM students studying in Higher Education has remained largely unchanged from 1986 to 2009 across STEM, including in the Physical Sciences, Biological Sciences and Engineering Sciences.

Overall, they found the number of STEM students in Higher Education had increased in proportion with the increasing numbers of students studying in higher education. Indeed, Smith and Gorard attribute the proportional increase in STEM student numbers to the overall expansion of higher education, over and above any specific intervention, such as those around gender or ethnicity, designed to recruit more STEM students. Smith and Gorard (2011) also found that the first destinations of the majority of STEM graduates are not directly related to their degree subjects, suggesting that the demand for entry level STEM professionals is adequately met by the current supply of graduates. The findings of Smith and Gorard suggest therefore that the numbers of STEM students at university have risen, in keeping with an overall increase in the numbers of university students, but that STEM students are unlikely to find STEM related work immediately after graduation.

In turning to employment after graduation, Smith and Gorard (2011) explored patterns for engineering students and found over 70% of engineering graduates found employment, and that this trend had been stable between 1994 and 2009. Their findings suggest less that 50% of engineering graduates were employed in professions related to their studies. Their analysis suggests that for engineering students, employment within the engineering sector is not always forthcoming, in spite of the perceived need for more engineers. Smith and Gorard (2011) argue, as a result, that the 'shortage thesis' is mistaken. It should be noted, however, that Smith and Gorard's study is a single piece of research and we refer to it to illustrate an alternative interpretation of the issues.

Section 5. STEM initiatives aimed at the formal and informal sectors

5.1 STEM initiatives in the formal sector

5.1.1 The school science curriculum

Within the last quarter of a century, the education system has been criticised, challenged and constricted by central government and others, whichever party has been in government. The increase in 'accountability', manifested in the introduction of a national curriculum, comprehensive nation-wide testing and rigorous inspection on a scale unique in the world, has had a major impact on many aspects of life in schools.

5.1.1.1 A history of change: towards a National Curriculum

Dissatisfaction with school science and, to some extent, mathematics education was evident in the USA and in the UK before the launch of the Sputnik satellite in 1957. Successive government reports and political commentary have continued to focus on the inadequacy of science and mathematics education in both primary and secondary schools. As a result, STEM education in English schools has been through a process of almost continual change since the 1960s. The most significant changes include the introduction of Nuffield Science; the move towards 'balanced science' (that is, the teaching of biology, chemistry and physics for all students) and the more recent introduction Triple Science; the rise of 'process science' (as opposed to focusing on 'the facts') and, more recently, the introduction of a National Curriculum and the associated assessment procedures. This rate of change endures – at the time of writing, the Government had just announced a 'slimmed down' National Curriculum with a focus on scientific facts and a greater emphasis on arithmetic.

Some of the more recent changes in STEM education owe something to external political and social factors and, more specifically, to research into girls' underachievement carried out as long ago as the 1970s and 1980s. At the same time, dissatisfaction with the quality of state education, highlighted by James Callaghan, the Labour Prime Minister in 1976, eventually resulted in the introduction of the National Curriculum by a Conservative government in 1988. The National Curriculum was designed, in part, to serve the needs of those who wished to compare schools by ensuring that all schools taught the same content so that their results could be compared more easily than was previously the case. The National Curriculum also addressed the criticisms of those who saw too many girls opting out of the physical sciences at the age of 14 by ensuring that all students studied elements of biology, chemistry and physics.

With the introduction of the National Curriculum, the concomitant national system of assessment, league tables and parental choice of schools, schools in the 1990s became more competitive. As a result of the general shift in education away from more collegial models of working (such as inter-school collaborations), teachers began to focus more on school improvement in isolation rather than through developing as a 'community of practice'.

5.1.1.2 Beyond 2000 and 21st Century Science

In *Beyond 2000*, a critique of science education at the turn of the 21st century, Millar and Osborne (1998) picked out what they considered to be the major developments in education, and particularly in science education in England since 1960. First, they identified 'the major curriculum innovation, undertaken by the Nuffield Foundation which ... gave greater emphasis to the role and use of experimental work' (p. 2002-3). Nuffield Science involved a more experimental, investigative approach to science education pedagogy than had previously been the case.

Second, Millar and Osborne noted another significant development in science education as the introduction of the comprehensive school system in the mid-1960s which led, *inter alia*, to the development of courses 'for the less academic pupil' (1998: 2003). This change had enormous implications for science pedagogy. Third, they noted that courses developed during the 1980s, aimed to increase the emphasis placed on the processes of science (that is, the skills necessary to undertake science experiments). Fourth, they noted the influence of the Department of Education and Science policy statement, *Science 5-16* (DES, 1985) which argued that all young people should have a 'broad and balanced' science education (that is, a curriculum containing biology, chemistry and physics throughout the school system) and occupying (for most pupils) 20% of curriculum time from age 14 to 16. Fifth, Millar and Osborne noted the impact of the introduction, in 1986, of the General Certificate of Secondary Education (GCSE) which resulted in a variety of science courses that included all three main sciences intended for all students. Sixth, they highlighted the introduction of the National Curriculum in 1989, which made science a 'core' subject in the curriculum for students aged 5 to 16.

The *Beyond 2000* report led to major revisions in the science curriculum with a greater focus on the role of science in society and on how science works. The most successful course that emerged was 21st Century Science. The move towards a model of science education that incorporated studies of the nature of science and of its applications was taken up by the major professional organisation for science teachers, the Association for Science Education. However, their original proposals, which promoted more 'attention to the nature of science and studies in environmental science, applied science and the interaction of science and society' proved unpopular with teachers, some of whom did not regard themselves as able to teach socio-scientific issues.

Early attempts to focus on the processes of science tended to take an atomistic and idealised view of what science involved. There is some disagreement among science teachers as to whether the amount of science enquiry has changed in recent years: NESTA's survey of 510 UK science teachers found that 42% thought that the amount had increased over the preceding ten years while 32% thought the opposite (NESTA, 2005: 7). In the same survey, 99% of the sample of science teachers believed that enquiry learning had a significant (83% - 'very'; 16% - 'a little') impact on student performance and attainment (NESTA, 2005, p.5).

5.1.1.3 Balanced science

In the late 1950s, Kerr wrote that '[t]he teaching of general science as an alternative to biology, chemistry and physics has been a controversial topic among science teachers since the Thompson Report of 1918' (1958-59: 156-7). General science was characterised as being of lower status than the separate subjects. Since the 1970s, there were more determined moves towards making science 'balanced' across the traditional divisions of biology, chemistry and physics. The rationale was usually expressed in terms of citizenship and living in the modern world (DES, 1985). If citizenship is not to be preferentially conferred upon one sector: male or female, advantaged or disadvantaged, good performers or poor performers, there then follows the problem of what form science education should take. Abandoning the opportunity for girls to drop physics and for boys to drop biology would, it was argued, lead to more equitable access to balanced science education for all (DES, 1985). The National Curriculum provided an opportunity to reconstruct science as an amalgam of aspects of the three sciences in the curriculum as a minimum entitlement for all state schools students reflecting science as it was experienced in students' everyday lives.

The history of the implementation of the National Curriculum is one of confusion and contestation. Few science and mathematics teachers objected to their subjects being core for all students. Some consensus resulted from the involvement of teachers in the curriculum working parties.

With the National Curriculum in place, it became much easier for the government to prescribe the content of initial teacher education. All teachers had to be prepared to teach the same curriculum and to use the same assessment system, therefore all initial teacher education courses needed to address identical issues.

5.1.1.4 Scientific investigation and its assessment

In response to some of the criticisms of earlier versions, the National Curriculum has been revised several times since its introduction. For example, the science curriculum was originally divided into more than 20 Attainment Targets. It was progressively reduced to four. The assessment system has also been changed substantially with a return to grades as opposed to levels for examinations at age 16.

When the National Curriculum was introduced, there was an element of teacher assessment particularly of the process of doing science. The implementation of this assessment approach was the cause of more controversy than the content of the curriculum itself. The major change was in terms of a shift towards more investigatory practical work than had previously been the case: students were encouraged to undertake experiments in a more exploratory manner. Nevertheless, the evidence from examination boards was that pupils began to achieve standards of work that were not being achieved prior to 1988.

Assessment procedures have also changed as the National Curriculum has been revised with a concomitant necessity for continuing professional development for science teachers. The situation is made more complicated by a recent emphasis in schools on formative assessment (often referred to as Assessment for Learning (AfL)) which incorporates major changes to the way that teachers assess, record and plan lessons.

5.1.1.5 The impact on teachers

The impact of the National Curriculum and its assessment on the teaching professional was, and continues to be, profound. Helsby and Knight noted that:

> The changes in the formal structures of in-service education and support for teachers (inset) which have accompanied the educational 'reforms' of recent years, have seriously restricted the opportunities for personal, professional development. (1997, p.149)

In their eyes, professional development had become 'heavily managed from the centre within tight budgetary constraints' (ibid. p. 149). For many teachers, opportunities for professional development in general, for example, masters degrees or one-day courses, seem scarcer now than they were ten years ago (see Section 5.1.3).

Others, such as the Royal Society, have noted the impact of the National Curriculum on aspects of science learning, such as the amount of practical work done in schools and the subsequent needs for training science teachers. A report from one of the Royal Society's working groups noted that since 1990 there have been many changes in science education including (Royal Society, 1997: 1): ‘an increase in the amount of pupil investigation, particularly where pupils follow up their own ideas’; ‘the continuing developments in science equipment, particularly Information Technology’; ‘an increased emphasis on matching learning demands to pupils’ prior attainment has also resulted in teachers developing alternative strategies for teaching particular topics’ and a ‘continuing search for more relevant practical work linked to real life applications’.

5.1.2 A return to separate sciences: the rise of ‘Triple Science’

The age of compulsory education in the UK was raised to 16 in 1972. The 11-plus examination which was a process of selection depending on attainment in literacy and numeracy was abandoned and by 1975 the majority of local authorities in England and Wales had moved to a comprehensive system of education. The existence of two examination systems available for 16 year-old students became more and more untenable and in 1988 they were combined into the General Certificate of Secondary Education (the GCSE).

Students wishing to study science from the age of 14 mainly chose from the three separate subjects - biology, chemistry and physics with no compulsion to do all three. Under the options system that was in place at the start of the fourth form (students aged 14/15) in secondary schools, girls tended to drop physics, and boys to drop biology as an examination subject with the effect not only of reducing future employment opportunities but also of narrowing the breadth of a general science education. Recognising this situation as unsatisfactory, the Association for Science Education, among others, campaigned for a ‘broad and balanced science education for all up to the age of 16’.
Traditionally the single subject syllabuses were written assuming a minimum of 10% of curriculum time. It was generally, but not universally agreed that 30% for all three subjects was too much for science given the demands of other subjects in the curriculum and so, after much debate, ‘Double-award’ science came into being in which biology, chemistry and physics were studied as a double subject in approximately 20% of curriculum time. This situation was reinforced when the National Curriculum required all schools to offer a broad science curriculum. Examinations in the separate sciences were still available but the requirements of the National Curriculum and pressures on the timetable meant that most schools did not now offer them during the 1990s and early 2000s.

The organisation and nature of the GCSE examination changed considerably in the years since it came into being as did the National Curriculum. A key aim in these changes has been to provide flexibility that catered for students with different interests and abilities. The introduction of modular courses was one of the main innovations and Double-award Science evolved into Core Science and Additional Science. However, as part of a drive to encourage more students to study science at a higher level, the government announced that from September 2008 all 14-year-olds achieving a Level 6 score in the Key Stage 3 national assessments would be entitled to study a ‘Triple Science’ GCSE course, covering physics, chemistry and biology.

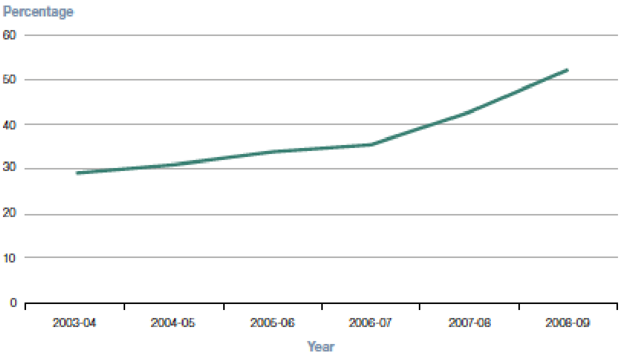
The demands of Triple Science are greater in breadth and depth than those of other GCSE science courses. Students need a greater level of ability and maturity to deal with the ideas and issues that are covered, and so selection is a complex process that requires them and their parents to be informed of the demands that will be made and the commitment required of them. Level 6 in the Key Stage 3 national assessment is a convenient starting point that helps in the decision-making but most schools seem to rely as much, if not more, on teacher judgement recognising that on-the-ground, in-depth knowledge of students is a more valid and reliable indicator than information obtained from two one-hour test papers.

The evidence from recent studies is that pupils studying ‘Triple Science’ are more likely than those studying combined science to continue science study at A-level and to achieve higher grades having done so. While starting from a low base, pupil take-up of the individual sciences has increased by almost 150 per cent in the last five years. According to the National Audit Office, the number of secondary schools offering ‘Triple Science’ has increased rapidly, although by June 2009 just under half still did not do so. There are wide variations across local authority areas. For example, in 2008/9 almost half of local authorities had 50 per cent or fewer of schools offering ‘Triple Science’, and only two areas had it available in every school.

Recent research shows that, compared with other pupils, pupils from more deprived backgrounds achieve relatively larger improvements in their future A-level science and mathematics outcomes when offered ‘Triple Science’ at GCSE than when offered only combined science. However, ‘Triple Science’ is less widely available in areas of higher deprivation, where it could potentially have the greatest impact on take-up and achievement.

Strongly correlated with the availability of ‘Triple Science’ is the provision of secondary schools with a specialism in science, technology, engineering or mathematics and computing, of which there are currently around 1,300 in England. According to the National Audit Office, on average over six per cent more pupils at these schools achieve A*-C at GCSE science than at other state secondary schools, and over two per cent more an A-C in A-level mathematics, biology, physics or chemistry. However, there are wide variations in provision between local authorities, again with a negative correlation between level of deprivation and the availability of such specialist schools.

Figure 5
Percentage of state secondary schools offering Triple Science GCSE, 2003-04 to 2008-09



NOTES
1 Schools are considered to offer Triple Science if at least one student entered physics, chemistry and biology in a single year.
2 Includes maintained secondary schools, academies and city technology colleges (England).

Source: National Audit Office analysis of National Pupil Database

5.1.3 The National Network of Science Learning Centres

A survey of teachers’ needs and wants (Dillon et al. 2000) concluded that there was a concern among science teachers about how they could develop personally and professionally throughout their careers. The lack of a system of continuous, personal professional development resulted in a severe disjuncture between teachers’ initial, pre-service training and their subsequent development something which continues to mark teaching out from other professions, notably medicine and engineering.

The survey confirmed what had been suspected about the professional development of science teachers by policy makers and academics for some time. Although there was some evidence of good practice – particularly effective local authority support, for example, the paucity of provision was seen as a major factor in the recruitment and retention of science teachers. Evidence from the survey and the associated focus groups suggested that schools did not have adequate funding to support their staff in the long-term, classroom-focussed coaching that characterised successful programmes such as Cognitive Acceleration through Science Education – a two-year programme of professional development which involved the whole science department in training in a new pedagogy based on a Piagetian view of child development. Even in science departments that had undergone CASE training there was evidence that some teachers benefited more from the professional development than others (Adey *et al.,* 1995). In short, the study indicated that science teachers, in common with all other teachers, lacked an established, well-defined structure of further training, accreditation and recognition. There was a distinct lack of a path of progression for teachers to systematically acquire further professional training that drew on anything more than restricted local networks and the voluntary interests and commitments of those who engaged with the work or activities of the ASE.

Teachers relied on local networks of informal contacts, either in-school or between schools, and a number of school-based training days which, because of their whole-school nature, rarely dealt with subject-specific issues. Schools and local education authorities rarely co-ordinated the dates of professional development days thus denying any opportunity for science teachers to meet and share common problems, issues and strategies.

Another problem identified in the study was that the implementation of the National Curriculum coincided with a substantial devolution of resources to schools resulting in a lack of any system-wide priorities at local or national level. HMI, the schools' inspectorate had commented as early as 1992 that:

> Teachers attended a range of courses but with many schools receiving devolved INSET funding, much of the INSET has been school-based ... Overall, however, the systematic identification and prioritisation of INSET needs, both individual and departmental, was not sufficiently common. (HMI, 1992: X)

The greater devolution of resources to schools in subsequent years, a major education policy, had not made the situation any better than it was in the early 1990s.

The survey formed the basis of the Council for Science and Technology's publication, *Science Teachers: A report on supporting and developing the profession of science teaching in primary and secondary schools* (CST 2000a). This report was designed to advise the government on how to improve science teaching in schools (CST, 2000b). The authors of the CST report argued that:

> there is considerable scope for securing a step change in science teachers' performance and hence in the science education of their pupils, by creating a pro-CPD culture, one in which a life time of professional learning is very much the norm. (CST, 2000a: 4-5)

The report recommended that the 'subject related CPD of individual teachers should be treated distinctly from other CPD requirements concerning whole school issues, matters of administration and national initiatives' (CST, 2000a: 29). The report also recommended that a 'core set of quality assured products and services is needed for science teachers to use in their own learning and development' (ibid.: 29). The report further recommended that:

> the Government should examine thoroughly the rationale, affordability and value of establishing a new body to act as the primary driver and agent for change and continuous improvement which we have simply termed as a 'national centre of excellence'. (CST, 2000a: 34)

The function of the centres broadened to include being a venue for teachers, scientists and industrialists would be able to meet although the rationale seemed to be that the last two groups could offer teachers 'innovative thinking' and 'advanced resources' – a clear deficit model of teachers and schools.

A 2001 Labour Party manifesto commitment that the national centre would be 'based at a leading university' was honoured although the National Science Learning Centre (which is based in York) is actually managed by a consortium comprising the Universities of Leeds, Sheffield, York and Sheffield Hallam.

The regional centres, which opened in 2004 and 2005 are mainly based in centres of science education. The Science Learning Centre London, for example, was originally managed by the Institute of Education in partnership with the Science Museum, Birkbeck College and University College London. At the time of writing, the regional centres are waiting to hear whether their application for further (significantly reduced) funding for two more years has been successful.

In the three years to 2008, the National Science Learning Centre received a contribution from the Wellcome Trust of £11m to building costs and £9m to running costs with a further £0.6m from government. From 2008 to 2013 the Wellcome Trust has agreed to contribute £10m towards core running costs including delivering 'Project ENTHUSE. The regional centres received £25.4m from the government for the three years to March 2008 with a further £18m for the three years to March 2011. Project ENTHUSE which came into operation in July 2008 provided bursaries for which teachers from every maintained school in the UK could apply. The grants covered fees, travel and accommodation for individual teachers, as well as the cost to schools of providing teaching cover. Project ENTHUSE provided £17m in bursaries from 2008 to 2013, including £10m from central government and £7m from industry.

In terms of impact, 80 per cent of science educators who participated in a Science Learning Centre course during 2007-08 felt it had a positive impact on their personal motivation, and 90 per cent were satisfied with the quality of training received (DCSF, 2008). In a similar survey in 2008-09, 82 per cent of participants reported that pupils had access to new and better learning activities, 73 per cent said that pupil motivation had improved, and 56 per cent indicated an improvement to pupil learning (NNSLC, 2009, p.16).

A more rigorous evaluation of the impact of the network was carried out by the National Audit Office, a body wholly independent of government. They reported in 2010 that 'participation by teachers in Learning Centre programmes is associated with improved teaching and learning, and higher take-up and achievement in science at their schools' but noted that 'take-up by teachers varies between areas' (p.6).

Figure 27

Difference between percentage of pupils achieving A*-C in separate GCSE sciences at schools with and without interventions

Intervention (units of measurement for which percentage change is reported are shown in brackets)	**Additional per cent of pupils achieving GCSE science A*-C in 2008-09 in schools with interventions**	**Additional increase between 2004-05 and 2008-09 in the percentage of pupils achieving GCSE science A*-C in schools with interventions**
Enhancement and Enrichment Activities (per activity)	0.245	0.252
STEM Ambassador activities (per activity)	0.525	–
Training days in National Science Learning Centre (per day)	0.136	0.099
Specialism in science, technology, engineering or maths and computing	6.342	2.808

NOTES

1 The GCSE data cited are for biology, but the results are strongly correlated across biology, chemistry and physics.

2 '–' indicates that results were not statistically significant.

Source: National Audit Office analysis of National Pupil Database and school-level intervention data

However, there is no evidence of causality – it may be that schools which are determined to improve are more likely to send their teachers for professional development.

5.2 Informal science education and engagement

5.2.1 Introduction

In addition to STEM education through school and university, a third landscape of science education and engagement takes place out of school. Referred to as 'informal' or 'life-long' science education, amongst other names, for the purposes of this report, we note that in the UK there has been considerable investment in science engagement and education activities in science centres, museums, science festivals, and other environments, that we will refer to here as informal contexts. Alongside activities designed to educate are a host of activities that fall under the broad banner of public engagement with science. These activities are less explicitly education, with a focus instead on science as part of culture or the political aspects of science in society. With the House of Lords (2000) report which foregrounded the political need for dialogue, debate and discussion on scientific issues in British society, new funding streams for science engagement activities meant that public engagement with science came to refer to educational, as well as cultural and political science engagement activities. As a result, the last 20 years has seen a blurring of informal science education activities with political and cultural science engagement, which has also meant a significant amount of science education and engagement has taken place outside schools and universities.

5.2.2 Mapping informal science education and engagement in the UK

As might be expected, from an institutional perspective the field of informal science education and engagement is extremely varied. Two recent reports commissioned by the Wellcome Trust suggest that organisations involved in informal science education are diverse. The first report suggests over 50 different types of organisation can be identified within the British informal science education sector (Falk et al., 2012) while the second report suggests these organisation range from theatre groups to providers of science 'shows' for schools (Lloyd, Neilson, King, & Dyball, 2012). Of these myriad organisations, the Falk *et al.* (2012) report suggests that while certain organisations may be more visible (for example, museums or science centres), the richness, flexibility and resilience of informal science education and engagement as a whole sector stems from the diversity of organisations involved.

In terms of who participates in informal science education and engagement, the picture is less varied. While a report for the Department of Business, Innovation and Skills (BIS) (Ipsos MORI, 2011) suggested that between 2010 and 2011 50% of the public had taken part in an informal science education and engagement activity, data suggests that this public was drawn from the more enfranchised, White, middle-class, urban half of the population, typically participating in family groups (Department for Culture Media and Sport, 2011; Ecsite-UK, 2008b). The activities included on the survey that informed the MORI report included science talks and activities outside school or university classes, visits to science centres, science museums, zoos, planetaria, science festivals, aquaria and botanic gardens. Therefore, although a significant part of the UK population takes part in informal science education and engagement activities, questions remain about why and how the 'other half' are less involved (Dawson, 2012).
When participants in informal science education and engagement activities are examined more closely, participants appear to be even less diverse. Across the informal science education and engagement sector as a whole, the vast majority of organisations concentrate on providing their services to young people, teachers and families. In particular, there is a focus on providing resources to school students between the ages of 5 and 19 (Falk et al., 2012). In contrast, there is remarkably little provision for the under 5's and adults over the age of 19. As a result, while the practices of organisations involved in informal science education and engagement may come under the rubric of life-long learning and public engagement with science, the majority of the activities that take place can be categorised as enhancement and enrichment activities aimed at those in the 'formal' school sector. Overall, therefore, what first appears to be a hugely wide range of different activities for different audiences, is in practice more narrowly framed. One argument behind this focus on student participants is the overwhelming presence of a recruitment agenda that motivates many practitioners to concentrate their efforts on those who can be convinced to pursue STEM subjects and, ultimately, STEM jobs (Falk et al., 2012).

The content of informal science education and engagement activities is also very varied with different organisations specialising in specific subjects. Understandably, the Institute of Physics concentrates on activities with physics content, while the Royal Academy of Engineering focuses on engineering based projects and organisations with a broader remit, such as the Science Museum or the British Science Association cover a broader range of STEM content. While many practitioners involved in informal science education and engagement activities refer to STEM in a broad sense, in practice 'science' is typically the main focus. As a result the number of initiatives aimed specifically at mathematics is much smaller than for science and technology. Most of these are enhancement and enrichment activities aimed at students of high ability. Mathematics is in principle a part of the many initiatives that have a broad STEM focus, but the informal impression is that it rarely figures significantly in them.

5.2.3 Informal science education and engagement: What difference does it make?

The impact of the informal science education and engagement sector as a whole is hard to establish though highly sought after by advocates of the field (Falk et al., 2012; Lloyd et al., 2012). Several British reports have gathered data internationally about the benefits of participation in informal science education and engagement activities, with a focus on attitudes towards STEM subjects in education, science in society and learning outcomes (Ecsite-UK, 2008a; Falk et al., 2012; Ipsos MORI, 2011). Data from international studies appears to support arguments about the value of informal science education and engagement opportunities for students and for adults. For example, results from a PISA study suggest that for 22 of the 31 OECD countries surveyed, students who participated in informal science education and engagement activities outside school achieved better test results in school, had greater faith in their ability to carry out science-related work and enjoyed science more than their peers who did not participate in such activities (OECD, 2012). Despite international studies, questions are increasingly asked about whether data from specific programmes in the UK can support the claims made for the benefits of participation in informal science education and engagement activities.

5.2.4 Science centres

One area of informal science education and engagement with published evaluation data involves a number of science centres in the UK. Science centres are a newer 'form' of institution in the UK and tend to follow the model of the Exploratorium in San Francisco. Notably, while the Labour Government nationalised the major UK museums, including the Natural History Museum and the Science Museum, science centres, like zoos, aquaria and botanic gardens, typically charge visitors for entry. At the turn of the last century the UK government, in collaboration with the Wellcome Trust, funded a series of 'millennium science centres'. The 18 centres that received this funding were not all new developments, some used the new resources to extend or redevelop their sites or programmes. It is also worth noting that across the UK there were many more science centres who did not receive this funding, for example the Frontier Economics (2009) report states that in 2009 there were 81 science centres in the UK. The Frontier Economics (2009) report was commissioned by the then Department for Innovation, Universities and Skills (DIUS) to establish whether UK science centres represented value for money, after two of the 18 'millennium' centres closed down within a decade of receiving the millennium funding package.

The Frontier Economics (2009) report examined 39 of the 81 science centres in the UK via a survey and collected financial information, carried out 5 case studies and compared these science centres to other informal science education and engagement organisations, in this case the British Science Association, STEMNET, RCUK and the Royal Academy of Engineering. The report concluded insufficient evidence was available on the long-term effects of science centres and other informal science education and engagement organisations to establish whether one type of organisation represented better value for money than another. On the basis of the collected data the report concluded science centres were as cost effective as the other informal science education and engagement organisations examined, on a cost per head basis. Furthermore, the report notes that while large science centres appear financially stable, smaller science centres are significantly less so. The report also notes the provision of extensive enhancement and enrichment activities for STEM students as well as CPD for STEM teachers, and concluded that these were appropriate for supporting the National Curriculum and teachers' needs.

The Frontier Economics report was accompanied by a report from the Wellcome Trust (2008) which reviewed the progress of the five science centres specifically supported by funds from the Trust (The Wellcome Trust invested around £14 million in 1997-8 in At Bristol, Birmingham Thinktank, Dundee Sensation, Glasgow Science Centre and Newcastle LIFE Science Centre (Wellcome Trust 2008). The Wellcome Trust report was based on interviews with staff at the 5 science centres and other stakeholders, telephone interviews with participants, teachers and local stakeholders, focus groups with school students, visitor observations and a visitor survey. The Trust's report concluded the five science centres acted as regional focal points for formal and informal science education activities. The report found the centres operated differently from one another, with little comparative evaluation data available to draw conclusions across sites about 'what works'. The report concluded the five science centres provided valuable learning experiences for local STEM students, their teachers and families, but struggled to build relationships with broader audiences. The Trust's report notes that the centres sometimes struggled to remain financially viable and aspects of their roles (for example, accessibility and widening audiences) could conflict with their need to operate on a business model.

The major take home finding of these two reports, which are to date the most extensive reviews available of British Science Centres, is that there is not enough evidence available to make strong claims about the effects of science centres on STEM students, teachers, families or local communities. In the wake of these reports the Association of Science and Discovery Centres (ASDC) published several reports on the roles and values of science centres, including advice on establishing evaluation indicators that would provide an overarching data set about the impacts of science centres (Ecsite-UK, 2008a, 2008b; The Association for Science and Discovery Centres, 2010). It should be noted, however, that to date, unlike the museum sector, no UK government has chosen to include science centres in central government funding budgets. It is also worth noting that although not based in the UK, there is a longitudinal survey study from the US carried out by Falk and Needham (2011) that found the Los Angeles science centre to have affected how the city's residents understood and related to science. Thus, while to date the evidence for the impact of UK science centres upon visitors and the population more broadly is very limited, there are an increasing number of international studies that suggest science centres provide valuable learning opportunities for visitors and may contribute more broadly to the scientific literacy and attitudes of broader communities.

5.2.5 The Science, Technology, Engineering and Mathematics Network (STEMNET)

A second aspect of the field of informal science education and engagement with evaluation data is the work of STEMNET. STEMNET (The Science, Technology, Engineering and Mathematics Network) is an educational charity that began in 1996 and runs three programmes aimed at improving the opportunities available to young people through STEM subject; the STEM Ambassadors, STEM Clubs Network and the Schools STEM Advisory Network. The work of STEMNET is notable for its reach, for example, STEMNET programmes run nationally with regional hubs set up across the UK. As a result it is one of the larger, co-ordinated informal science education and engagement programmes running in the UK. For example, STEMNET currently manage 25,000 STEM Ambassadors working with over 600,000 young people and 20,000 teachers each year. STEMNET works with over 3,000 UK employers and adds over £12 million a year into STEM enhancement and enrichment activities for schools, colleges and universities. A proportion of the £12m is 'in kind' via the volunteering of STEM Ambassadors and STEM industry.

The STEMNET programmes were evaluated in 2011 by the National Foundation for Education Research (NFER). NFER collected data via telephone surveys of 500 STEM subject teachers, a survey of 176 pupils who had undertaken STEMNET activities in the previous year, a survey of 419 students from STEM clubs, in depth research with 14 schools who had been involved with a STEMNET programme and analysis of existing STEMNET evaluation data.

The NFER (Straw, Hart, & Harland, 2011) report found teachers and students both rated the STEM Ambassadors programme as increasing interest in and knowledge of STEM subjects, enjoyment of STEM subjects, knowledge about studying STEM and STEM careers. The majority of interactions between schools and STEM ambassadors were one-off rather than longer-term relationships, with most surveyed students engaging with a STEM ambassador once, often via listening to a talk. The STEM clubs were rated by students and teachers as having the same positive effects as interactions with STEM ambassadors, in other words, increasing interest in, enjoyment and knowledge of STEM subjects, studies and careers. STEM clubs were also found to increase students practical skills in STEM subjects. Interestingly, more effects were noted in relation to improved attitudes and knowledge towards science and technology, with less effect in relation to engineering and maths. This difference may however be explained by the higher number of clubs with a focus on the S and T of STEM than the E and M. More students involved in STEM clubs reported a larger impact than students only involved in

STEM ambassador programmes, which the NFER report concluded was likely to be related to the longer term, in-depth nature of participation in a STEM club, compared to a one-off interaction with a STEM ambassador.

The report also found teachers and schools felt the brokerage aspect of STEM advisory networks valuable in supporting their work. Thus, overall, the report suggests the STEMNET programmes were enhancing the STEM learning experiences of students in a variety of ways. What is notable however, is the limited data available about the relationship between involvement in STEMNET activities and student achievement, which the report is unable to make strong claims about. Overall, therefore, the report presents evidence that the three STEM enhancement and enrichment activities delivered through STEMNET are valued by students, teachers and schools, through self-report data that suggests these participants perceive the STEMNET programmes have an effect on their attitudes and knowledge about STEM, but are not able to correlate these findings with student achievement.

5.2.6 Mathematics initiatives

As mentioned above, there are far fewer informal science education and engagement projects based explicitly on mathematics content. One of the most significant of the mathematics-based initiatives is the Millennium Mathematics project, based at the University of Cambridge. This is a long-standing mathematics education initiative which runs a range of programmes and events aimed at school children and at the general public. One of its activities, NRICH, is an online project based in both the University of Cambridge's Faculty of Education and the Centre for Mathematical Sciences. It encompasses:

- the main NRICH website, publishing free mathematics enrichment resources for pupils of all ages, including discussion forums,
- face-to-face outreach activity and CPD for teachers.

NRICH has been going since 1996. It started life as a resource explicitly aimed at very able students, but has since broadened its objectives to support all students. How successful it has been in this respect I do not know. In general it is well supported and well regarded. The usage figures are impressive. The MMP also runs a programme of travelling 'Roadshows' which visit schools. However, as mentioned in the NFER report (Straw et al., 2011), mathematics, along with engineering, may lose out in the broader landscape of informal science education and engagement activities where the focus appears to be more on science and technology content.

5.2.7 The wider perspective

Across the field of informal science education and engagement as a whole, questions remain about what difference the organisations involved actually make from the perspective of participants. Of the limited data available, the majority is focused on specific events and even in the case of broader evaluation programmes such as the ones described above, it is hard to draw comparisons across different aspects of the field. Furthermore, the majority of existing research is based on participants' self-reported data, doubtless because the resources required to research in detail the links between participation in informal science education and engagement activities, students achievements, broader attitudes, values and scientific literacy within communities and the population as a whole. What is clear is that informal science education and engagement represents a significant field of STEM related activity in the UK, enjoyed by half the population in their leisure time and in more structured ways by STEM students and their teachers. What the big picture impacts of these activities are, however, are harder to ascertain.

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ANNEX 1 THE ENGLISH EDUCATION SYSTEM

School years [edit]

The table below describes the most common patterns for schooling in the state sector in England. In most cases progression from one year group to another is based purely on chronological age, although it is possible in some circumstances for a student to repeat or skip a year. Repetition may be due to a lack of attendance, for example from a long illness, and especially in Years requiring standard tests. A child significantly more advanced than their classmates may be forwarded one or more years.

Age at birthday during school year[14]	Year	Curriculum Stage	Schools		
4	Nursery	Foundation Stage	Nursery School		
5	Reception		Infant School	Primary School	First School
6	Year 1	Key Stage 1			
7	Year 2				
8	Year 3	Key Stage 2	Junior School		
9	Year 4				
10	Year 5				Middle School
11	Year 6				
12	Year 7	Key Stage 3	Secondary School	Secondary School with Sixth Form	
13	Year 8				
14	Year 9				Upper School or High School
15	Year 10	Key Stage 4 / GCSE			
16	Year 11				
17	Year 12 (Lower Sixth)	Sixth Form / A-level, International Baccalaureate, Cambridge Pre-U, etc.	College/Sixth Form		
18	Year 13 (Upper Sixth)				

In the vast majority of cases, pupils progress from primary to secondary levels at age 11; in some areas either or both of the primary and secondary levels are further subdivided. A few areas have three tier education systems with an intermediate middle level from age 9 to 13.

(source: Wikipedia)

APPENDIX 6: HIGHER EDUCATION STATISTICS AGENCY DATA (HESA)

First Degree Qualifiers from UK HEIs, excluding the Open University[1]

Subject of Study	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	% change 02/03 to 09/10	% change 08/09 to 09/10
Medicine and Dentistry	6,175	7,005	7,445	7,700	8,260	8,470	9,100	9,335	51%	3%
Subjects allied to medicine	23,665	24,705	27,865	29,775	30,460	32,505	31,390	33,025	40%	5%
Biological Sciences	23,725	24,925	26,375	26,975	28,135	30,285	30,185	31,440	33%	4%
(C1) Biology	4,430	4,480	4,580	4,445	4,670	4,680	4,625	4,685	6%	1%
(C6) Sports Science	3,745	4,975	5,630	6,210	6,325	7,495	7,855	8,370	123%	7%
(C8) Psychology	8,900	9,680	10,615	11,345	11,655	12,615	12,175	12,650	42%	4%
Veterinary Science	560	660	690	680	645	740	810	780	39%	-4%
Agriculture and related subjects	2,150	2,415	2,225	2,140	2,185	2,295	2,185	2,260	5%	3%
Physical Sciences	12,475	11,980	12,200	12,530	12,270	12,855	13,225	13,490	8%	2%
(F1) Chemistry	2,955	2,735	2,705	2,520	2,665	2,825	2,930	3,100	5%	6%
(F3) Physics	2,205	2,180	2,225	2,345	2,255	2,255	2,490	2,575	17%	3%
(F4) Forensic and Archaeological Science	385	520	745	1,195	1,445	1,640	1,710	1,710	344%	0%
Mathematical Sciences	5,100	5,150	4,990	5,260	5,385	5,560	5,840	6,305	24%	8%
Computer Science	18,240	20,010	19,775	18,495	16,255	14,735	13,860	14,090	-23%	2%
Engineering and Technology	19,455	19,585	19,340	19,535	19,495	20,150	20,540	21,670	11%	6%
Engineering	17,520	17,560	17,300	17,345	17,120	17,595	17,950	18,910	8%	5%
Technology	1,940	2,030	2,040	2,190	2,380	2,560	2,590	2,760	42%	7%

Architecture, Building and Planning	6,555	6,735	6,565	7,365	7,615	8,655	8,905	10,385	58%	17%
TOTAL STEM	118,105	123,165	127,475	130,450	130,705	136,260	136,035	142,785	21%	5%
TOTAL NON-STEM	156,340	161,825	169,540	175,460	179,960	189,850	189,160	199,060	27%	5%
TOTAL	274,445	284,990	297,015	305,910	310,665	326,110	325,195	341,845	25%	5%
% 'science'	43%	43%	43%	43%	42%	42%	42%	42%		

Source: Higher Education Statistics Agency (HESA).
Notes: Figures are based on a qualifications obtained population and have been rounded to the nearest five.
(1) Figures exclude entrants from the Open University due to inconsistencies in their method of recording subject of study over the time period.

Masters Degree Qualifiers from UK HEIs, excluding the Open University(1)

Subject of Study	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	% change 02/03 to 09/10	% change 08/09 to 09/10
Medicine and Dentistry	1,525	1,855	2,015	2,255	2,350	2,415	2,535	2,775	82%	9%
Subjects allied to medicine	3,215	3,910	4,095	4,430	4,930	5,575	6,230	6,425	100%	3%
Biological Sciences	3,880	4,515	4,810	5,485	5,595	5,660	6,200	6,725	73%	8%
Biology	580	545	640	760	750	950	1,005	1,135	96%	13%
Sports Science	230	285	365	445	445	455	620	660	187%	6%
Psychology	1,990	2,305	2,370	2,855	2,780	2,825	3,045	3,285	65%	8%
Veterinary Science	55	45	75	75	80	80	90	80	45%	-11%
Agriculture and related subjects	785	900	895	910	870	815	960	915	17%	-5%
Physical Sciences	2,765	3,310	3,370	3,510	3,540	3,790	3,695	4,155	50%	12%
Chemistry	375	450	430	395	410	475	455	515	37%	13%
Physics	290	305	335	335	340	400	370	460	59%	24%
Forensic and Archaeological Science	295	350	440	575	595	535	555	570	93%	3%
Mathematical Sciences	760	975	1,265	1,120	1,200	1,230	1,285	1,310	72%	2%

Computer Science	6,490	6,365	6,790	6,485	6,145	6,590	6,015	7,625	17%	27%
Engineering and Technology	6,270	7,635	8,960	9,375	9,215	9,890	9,920	12,250	95%	23%
Engineering	5,435	6,835	8,145	8,555	8,430	8,870	8,870	11,125	105%	25%
Technology	830	800	810	825	790	1,015	1,045	1,125	36%	8%
Architecture, Building and Planning	1,850	2,225	2,630	3,290	3,305	3,905	4,220	5,060	174%	20%
TOTAL STEM	27,590	31,740	34,900	36,935	37,235	39,955	41,145	47,320	72%	15%
TOTAL NON-STEM	52,930	61,610	65,885	69,270	71,375	76,775	80,130	89,850	70%	12%
TOTAL	80,520	93,350	100,790	106,200	108,610	116,730	121,275	137,170	70%	13%
% STEM	34%	34%	35%	35%	34%	34%	34%	34%		

Source: Higher Education Statistics Agency (HESA).
Notes: Figures are based on a qualifications obtained population and have been rounded to the nearest five.
(1) Figures exclude entrants from the Open University due to inconsistencies in their method of recording subject of study over the time period.

PhD Qualifiers from UK HEIs, excluding the Open University(1)

Subject of Study	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	% change 02/03 to 09/10	% change 08/09 to 09/10
Medicine and Dentistry	1,360	1,530	1,565	1,745	1,730	1,785	1,970	1,945	43%	-1%

Subjects allied to medicine	885	875	930	905	955	1,005	965	1,080	22%	12%
Biological Sciences	2,350	2,380	2,470	2,470	2,595	2,475	2,600	2,925	24%	13%
Biology	680	630	610	625	670	620	710	655	-4%	-8%
Sports Science	45	70	70	80	85	55	80	120	167%	50%
Psychology	775	730	795	825	895	955	955	1,270	64%	33%
Veterinary Science	70	60	95	85	80	70	50	55	-21%	10%
Agriculture and related subjects	230	260	215	230	175	125	175	160	-30%	-9%
Physical Sciences	2,160	2,265	2,315	2,275	2,385	2,190	2,280	2,495	16%	9%
Chemistry	995	1,035	1,020	965	1,040	885	900	1,025	3%	14%
Physics	605	565	555	630	660	590	655	675	12%	3%
Forensic and Archaeological Science	40	45	50	40	50	40	35	60	50%	71%
Mathematical Sciences	370	415	410	445	465	445	425	515	39%	21%
Computer Science	370	465	545	710	715	715	790	840	127%	6%
Engineering and Technology	2,005	2,030	2,005	2,190	2,385	2,130	2,380	2,520	26%	6%
Engineering	1,735	1,795	1,800	1,950	2,135	1,895	2,095	2,215	28%	6%
Technology	270	235	205	240	250	235	280	305	13%	9%
Architecture, Building and Planning	170	185	240	195	250	225	250	250	47%	0%
TOTAL STEM	9,970	10,465	10,780	11,255	11,730	11,160	11,885	12,780	28%	8%
TOTAL NON-STEM	4,785	4,680	4,860	5,130	5,680	5,355	5,660	5,865	23%	4%
TOTAL	14,755	15,145	15,640	16,385	17,405	16,520	17,545	18,645	26%	6%
% STEM	68%	69%	69%	69%	67%	68%	68%	69%		

Source: Higher Education Statistics Agency (HESA).

Notes: Figures are based on a qualifications obtained population and have been rounded to the nearest five.
(1) Figures exclude entrants from the Open University due to inconsistencies in their method of recording subject of study over the time period.