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Chapter 10 – United Kingdom

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Introduction

In this chapter we focus on science, technology, engineering and mathematics (STEM) education in the United Kingdom. We examine government policy and describe various strategies and programmes that have been designed and implemented with a view to improving the system. The UK, and particularly England, provides a case study of high stakes accountability regimes. Root and branch changes have seen major changes in curriculum and assessment at a number of levels as well as an attempt to impose a national pedagogic strategy.

We begin by taking a critical look at the arguments that continue to be used to justify investment in STEM education. In subsequent sections we examine some of the changes that have been imposed on schools and universities and at the impacts of those changes.

The relevance of STEM to economic growth and well-being

The official view

> 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.[i]

Lord Sainsbury's 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 successive governments, by all major political parties, by the institutions that represent science and technology, by the learned societies and by industry.[ii]

Over the past twenty or so years, numerous policy reports have explored and expanded on this thesis. A key document is the Treasury's ten-year review, *Science & Innovation Investment Framework 2004-2014*.[iii] This report, commissioned by the

Labour Government, set the long-term policy agenda for STEM in the UK. The review sets out some high level ambitions. From the educational perspective the key objectives are:

> 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

and,

> 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.[iv]

These ambitions have been strongly influential in setting the policy direction and have been pursued by governments of both political sides.

The concerns that drive this policy agenda include:

- globalisation, and in particular the growth of the Asian economies;
- the restructuring of companies into providers of high-value goods, services and industries;
- the importance to this ambition of highly trained STEM personnel;
- concern that the supply of science graduates is inadequate;
- a conviction that the solution lies in action at schools and in higher education (HE), particularly the former;
- a tendency to frame the issue of the supply of trained STEM personnel in terms of a pipeline;
- a preoccupation with the results of large-scale international comparative studies, especially TIMSS and PISA.

Many developed countries have similar concerns. There are, in addition, aspects that are specific to the UK, in particular: the comparative strength of UK STEM research; the international strength of research in UK universities; the historic weakness of the UK in turning science into technological innovation; the important role of the Europe Union (and the UK's perpetually uneasy relationship with it); and particular weaknesses in our school and HE systems.

STEM and the labour market

Most research tends to support the official view about the importance of STEM training to the labour market. The authoritative House of Lords (2012) report, *Higher Education in Science, Technology, Engineering and Mathematics (STEM) subjects,* for example, 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.[v]

The House of Lords report makes the point that an increase in STEM graduates would benefit the economy *regardless* of whether they went into a STEM career or not. Likewise the CIHE evidence suggests that STEM graduates and their skills are a valuable resource above and beyond the needs of the STEM labour market.

In terms of future demand, Wilson's[vi] report for the CIHE suggested STEM graduates were slightly more likely to be employed than other graduates in 2007, but that the difference was minimal. In terms of future projections however Wilson's report suggested a rising demand over time for those qualified to a high level in STEM subjects. There are of course counter views. Research by Emma Smith and Steven Gorard for example has questioned whether prevailing rhetoric from government and the science lobby is justified in presenting the recruitment of STEM students as a cause for concern.[vii]

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 commentators dating the start of the "public understanding of science" movement to the launch of the Bodmer Report in 1985.[viii] The most up-to-date public data, based on nationally representative samples, come from the government commissioned Ipsos MORI surveys 'Public Attitudes to Science'.[ix]

The 2011 survey suggests there is strong general support for the view that science contributes directly to the economy, and to its growth. The specific links between science 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. However, the public do appear to perceive science as important for the long-term growth of the economy and in terms of the ability of the UK to compete in international markets.[x] In this sense, study participants reflected the "official" view of the role of science in the economy.

The 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. 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,[xi] 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 uptake of STEM in education

The UK education system

Background

We begin with an overview of the UK education system. 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 53 million), Wales (3 million) and Northern Ireland (2 million) are similar to each other. Scotland (5 million) differs in important respects, in particular at upper secondary level. In this chapter, school level data usually refer to England or to England and Wales combined.

Schools

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. Children must receive a full-time education from the age of 5 and in most parts of the country children attend primary schools from 5 to 11. At age 11 most children transfer to all ability ("comprehensive") state schools although there are significant variations to this pattern.

Historically, state schools have been run by local education authorities, of which there were 174 in England and Wales. In recent years schools have been encouraged to become "academies", funded centrally by the state and independent of local authority control. A significant number of schools are able to select a proportion of their intake and a small but growing number of "free" schools have been introduced, based on the Swedish model. A number of secondary schools have been granted the status of specialist schools. The number of specialist schools in science, technology, engineering or mathematics and computing is currently around 1,300 in England.

An important effect of this change has been to reduce the power of local authorities and the diminution or loss of their ability to provide advice. In the field of STEM this advice has historically been important. We describe later in the chapter various initiatives that have been put in place to replace local authority support.

Some 7 per cent of pupils attend private ("independent") schools with the figure rising to around 18 per cent for students over the age of 16. There are 164 selective ("grammar") schools in areas which resisted the move to comprehensive education. The great majority of pupils in these schools come from higher socio-economic groups. While the numbers of their students are small, the independent and grammar schools have a disproportionate effect on the higher echelons, especially in STEM. The relative lack of equity of access to higher education has been an issue in the UK for decades.

The National Curriculum and national testing

Since 1988 schools in England, Wales and Northern Ireland have had a National Curriculum. 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 around 20 per cent of curriculum time and, along with English, constitute the "core" subjects, which are compulsory from 5-16. All pupils take national 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 particularly as schools' results are compiled in to league tables by the media.[xii]

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

Upper secondary education ("post-16")

After GCSE, the more academic students (some 50 per cent of the cohort) stay on at school or college for another two 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. At the time of writing this two stage process is under review by the government.

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. Most schools will offer a menu of 10-15 subjects at A level and students tend to specialise either on the science or the arts/humanities side. 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 per cent of the age cohort become NEET (not in education or training).

Teachers

Teaching in the UK is a graduate profession. The completion of a course of Initial Teacher Training (ITT) is necessary in order to attain Qualified Teacher Status. The number of routes into teaching has increased in recent years with increasing emphasis on what are termed “school-based” (as opposed to “university-based”) schemes. This is a contentious area and the current government seems determined to reduce the influence of university education departments on teacher training.

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 165 universities (i.e. bodies that award degrees) in the UK. All but a handful are public institutions. In 2010/11 around 75 per cent of UK university research funding went to the 24 larger and older universities, known as the “Russell Group”.[xiii]

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 per cent of young people should go to university. Since then, the number of students going on to higher education has risen sharply, to the point where around 30 per cent of men and 40 per cent 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.[xiv] The expansion of the universities has been one of the major factors in the changing picture of STEM education in the UK.

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 per cent of students went to university. Numbers taking them have grown hugely and pass rates have increased steadily. This trend 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 arrangement 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.[xv]

Until 1998, university education was essentially free to home students, paid for through central government grants to universities. In 1998, fees were introduced, at the relatively low level of £1,200 pa. At the same time, a loan system was introduced with students paying back their loans via the taxation system once they begn 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 whatever fees they wished, to a maximum of £9,000 pa.

International comparisons and the UK education system

According to a recent analysis of education systems, the UK is ranked sixth best in the world.[xvi] 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. 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.[xvii]

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.[xviii] 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. There are strong arguments to suggest that these numbers are not nearly as dramatic as they appear,[xix] but for all that 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 uptake of STEM in education - schools

STEM in schools – Primary

Mathematics and science are compulsory for all pupils until the age of 16. At the end of primary school pupils take national tests in mathematics and English. National testing in science was stopped in 2008. In 2012 84 per cent of pupils in England achieved the target in mathematics in the national tests. There was no difference in performance between boys and girls.

Performance in mathematics has improved markedly over the past fifteen years. In 1998, only 59 per cent of pupils achieved the target level. That number rose to 72 per cent by 2000 and has been rising steadily but more slowly ever since. The causes are debated, but it seems likely that the large gains in the early years may have been linked to the introduction of a National Numeracy Strategy in the late 1990s. The strategy for English appears to have had a similarly large effect. The secondary strategies which followed seem to have been much less effective.[xx]

STEM in schools – lower secondary (11-16)

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

At Key Stage 4, science is taught as a “double subject” – that is, it is equivalent in value to two GCSEs and takes up about20 per cent of teaching time. Physics, chemistry and biology are usually taught separately, although the curriculum is coordinated. Pupils are normally taught by subject specialists, although a shortage of physics teachers, in particular, means 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.[xxi]

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.

Take-up and achievement in science at GCSE

The data in the following sections are taken from a recent report from the National Audit Office[xxii] which summarised the trends in STEM take up and achievement from 2001/2 to 2009/10.

- The great majority of pupils will take some form of science GCSE. The proportion of pupils studying any GCSE science subject declined slightly between 2001/02 and 2005/06, but recovered from 2005/06 to 2009/10.
- Take-up of the separate sciences grew by almost 150 per cent between 2004/05 and 2009/10, with a corresponding decline in the numbers taking double science options.
- Measured by the percentage of students who have achieved the benchmark A*-C grade, GCSE achievement in maths and science has shown a steadily rising trend over the period of the study.
- The percentage achieving grade A*-C in double science rose from 52 per cent to > 61 per cent
- The percentage achieving grade A*-C in separate sciences rose from 90 per cent to 94 per cent. These improvements were achieved at the same time as increased take-up. There is no significant difference in attainment between the three sciences.
- The percentage achieving grade A*-C in mathematics rose from 52 per cent to 65 per cent.

STEM in schools – upper secondary

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

Trends in A-level entries in maths and science subjects between 2001/02 and 2009/10

There have been concerns about the numbers of students opting to take STEM A levels for many years. Numbers taking biology and chemistry have remained fairly constant, but physics has shown a long-term decline. Mathematics has likewise shown a long-term decline. The situation seemed to be improving until the early 2000s when a change to the curriculum led to a very sharp drop, of the order of 10 per cent in one year.

These concerns led to the government setting 10-year improvement targets in 2005/6. By 2014, according to the plan, entries to physics A level would be 35,000 (up from 24,200), chemistry 37,000 (33,300) and mathematics 56,000 (46,168).

By 2009/10 entries for mathematics had increased to nearly 70,000. The Department of Education has since raised the target 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 79 per cent of the 2014 target level. Biology entries have increased by 16 per cent since 2001/02, to around 52,000. Seen as a proportion of the age cohort these numbers also show a rising trend.

Achievement at A level

Attainment at A level is on a rising trend. The proportions of entrants achieving grades A-C in A level mathematics, biology, chemistry and physics all increased between 2001/02 and 2009/10: Mathematics rose 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.

While these figures are robust their interpretation is contested (as indeed are the rising trends in attainment in GCSEs and A levels generally). There are those who say that they speak more of the declining difficulty of examinations than they do of increased attainment. The present government has taken this seriously and has instituted a set of reforms that will be introduced over the coming years.

Mathematics

A level mathematics has as its core objective the preparation of students for higher education courses in mathematics, physics and engineering. Most of the students taking A level have a grade A or better at GCSE.

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 per cent of students continue with mathematics after the age of 16. This is exceptionally low by international standards. In a recent study[xxiii] of 24 OECD countries no country outside England, Wales and Northern Ireland had a participation rate lower than 50 per cent and most had participation rates of 75 per cent or better.
These are recognised by government as serious problems and upper secondary (post 16) mathematics is one of the most active education policy areas at the moment.

The uptake of STEM in education – universities

Overview

As discussed above, there has been a significant expansion in rates of participation in higher education since the late 1990s. In 2010/11 there were slightly fewer than 2.5 million students in higher education institutions. Of these around 60 per cent were taking first degrees, 20 per cent taught masters degrees and 5 per cent research degrees (PhDs). A significant trend has been the growth in demand from international students undertaking masters-level qualifications. The number of international students studying at UK universities has risen significantly. The number of non-EU students rose from 8 per cent of the total student population to around 12 per cent in the eight years from 2002/3.[xxiv]

The traditional route has been that students enter university straight from school (or possibly after a "gap year") and study for a three-year bachelor's degree. While this is still the modal pattern, the picture has become more diverse and the number of part-time and mature students has risen significantly in recent years. Most students complete their bachelor degrees within three years. There has been a move towards four-year courses in STEM subjects, particularly engineering and physics, leading to an integrated masters degree. A masters degree is an essential requirement for Chartered status (i.e., licence for professional practice) in some areas, especially engineering.

STEM in higher education

Based on a broad definition of STEM subjects the number of graduates in STEM subjects at undergraduate level increased from approximately 118,000 in 2002/03 to over 140,000 in 2009/10. The number of STEM students has increased more or less in proportion to the increase in overall numbers. However a significant proportion of that growth has taken place in new disciplines, for example sports science and forensic science. The traditional science disciplines have grown only slightly, as has engineering. Over the eight year period 2002/03 to 2009/10, for UK domiciled students:

- Engineering decreased by 3 per cent (12,450 to 12,100)
- Chemistry was unchanged (2,750)
- Biology increased slightly (4,150 to 4,275)
- Mathematical sciences increased by 11 per cent (4,600 to 5,200)
- Physics increased by 11 per cent (2,050 to 2,300)

- Computer science dropped by 27 per cent (18,240 to 14,090) (figure includes overseas students).

These numbers are an improvement on the previous decade, when there was a significant drop in the number of students studying these core subjects. They are however set against an increase in the number of graduates of 20 per cent. Much of the growth in STEM numbers has taken place in newer, non-traditional subjects. The numbers in sports science, for example, rose by 122 per cent over the period (3,650 to 8,120) and the numbers in forensic and archaeological science rose by 349 per cent (360 to 1,615).

Postgraduate numbers

The number of students taking masters degrees in STEM subjects rose by 30 per cent over the eight year period 2002/3 to 2009/10, similar to the increase in non-STEM subjects (34 per cent). Numbers of students taking computer science and chemistry declined significantly (by 45 per cent and 12 per cent respectively). Conversely there were large increases in sports science (172 per cent) and forensic and archaeological science (94 per cent). These data relate to UK domiciled qualifiers, the trends look different when taking into account EU and overseas students.

The number of STEM PhD students increased by 15 per cent over the eight year period, the same as for non-STEM subjects. There were significant declines in chemistry (11 per cent) and biology (16 per cent).

STEM initiatives aimed at the formal and informal sectors

STEM initiatives in the formal sector

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); the rise of "process science" (as opposed to focusing on "the facts"); the introduction of a National Curriculum and the associated assessment procedures, and more recently the introduction of Triple Science. The arrangements for in service support for teachers have also changed radically in the last ten years. In this section we discuss the last three of these changes.

The National Curriculum and accountability

The National Curriculum, introduced in 1989, was designed, in part, to serve an accountability agenda by ensuring that all state schools taught the same content so that their results could be compared more easily than was previously the case. The science element of 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 along with a concomitant national system of assessment, league tables and parental choice of schools, schools in the 1990s were challenged to become 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".

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.

A return to separate sciences: the rise of Triple Science

Before the introduction of the National Curriculum, students wishing to study science from the age of 14 chose from the three separate subjects - biology, chemistry and physics, with no compulsion to do all three. Traditionally the single subject syllabuses were written assuming a minimum of 10 per cent of curriculum time. It was generally, but not universally agreed that 30 per cent 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 per cent 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.

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. 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.

The National Network of Science Learning Centres

A survey of teachers' needs and wants[xxv] concluded that there was a concern among science teachers about how they could develop personally and professionally throughout their careers. 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.

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*.[xxvi] 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 (based in York) is actually managed by a consortium comprising the Universities of Leeds, Sheffield, York and Sheffield Hallam. There is in addition a network of regional centres, which opened in 2004 and 2005. These too are mainly based in universities.

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 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.

Informal science education and engagement

Introduction

In addition to STEM education through school and university, there is a landscape of science education and engagement that takes place out of school. In the UK there has been considerable investment in science engagement and education activities in science centres, museums, science festivals, and other environments.

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 educational, 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 emerged. As a result the term "public engagement with science" came to refer to educational, as well as cultural and political science engagement activities. That is to say, engagement moved from mainly being about the public engaging with scientists on issues such as genetic modification of crops to include almost anything that would have been labelled as "public understanding of science" such as TV shows and talks. 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 now takes place outside schools and universities.

In terms of who participates in informal science education and engagement, a report for the Department of Business, Innovation and Skills (BIS)[xxvii] suggested that between 2010 and 2011 50 per cent of the public had taken part in an informal science education and engagement activity. The data suggest that this public was drawn from the more enfranchised, white, middle-class, urban half of the population, typically participating in family groups.[xxviii]

The impact of the informal science education and engagement sector as a whole is hard to establish. Data from international studies appear to support arguments about the value of informal science education and engagement opportunities for students and for adults. For example, results from the PISA 2006 study suggest that for 22 of the 31 OECD countries surveyed, there was an association between students who participated in informal science education and engagement activities outside school and higher test results in school. The students 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.[xxix] These associations do not, of course, provide evidence of causality.

In terms of national coverage, two of the largest innovations in the informal sector have been the Millennium Science Centres and STEMNET - The Science, Technology, Engineering and Mathematics Network. 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.

A study commissioned from Frontier Economics[xxx] by the Department of Business, Innovation and Skills attempted to survey the 81 science centres in the UK. Researchers collected financial information from just under half of the institutions and carried out five case studies, comparing these science centres to other informal science education and engagement organisations, in this case the British Science Association, STEMNET, the Research Councils UK and the Royal Academy of Engineering. The report concluded there was insufficient evidence 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.

STEMNET is an educational charity which runs programmes aimed at improving the opportunities available to young people; the STEM Ambassadors, STEM Clubs Network and the Schools STEM Advisory Network. The work of STEMNET is notable for its reach. 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. STEMNET currently manages 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.

Conclusion

The UK, and particularly England, provides a case study of high stakes accountability regimes maintained over a number of years and under successive governments of different political persuasions. Education in England has been a political football for many years and there is no sign that the game is over.

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Endnotes

[i] Lord Sainsbury, quoted in The Race to the Top: A Review of Government's Science and Innovation Policies, 2007, p. 3.
[ii] See, for example, Roberts, 2002.
[iii] HMSO, 2004.
[iv] HMSO, 2004, p. 6.
[v] House of Lords, 2012, p. 9.
[vi] Wilson, 2009.
[vii] See Gorard & Torgerson, 2012; Smith, 2010; Smith & Cooke, 2011; Smith & Gorard, 2011.
[viii] Royal Society, 1985.
[ix] See, for example, Ipsos MORI, 2011.
[x] Ipsos MORI, 2011.
[xi] See, for example, Michael, 2006.

[xii] See, for example, Harlen & Deakin Crick, 2002.
[xiii] For an up to date overview of higher education in the UK see: *Patterns and trends in UK higher education 2012*, Universities UK (2012): http://www.universitiesuk.ac.uk/highereducation/Documents/2012/PatternsAndTrendsinUKHigherEducation2012.pdf
[xiv] See http://www.bbc.co.uk/news/education-11438140
[xv] Hodgen et al., 2010.
[xvi] Pearson, 2012.
[xvii] Universitas, 2012.
[xviii] DfE, 2011.
[xix] Smithers, 2013.
[xx] DfE, 2012.
[xxi] Bell & Donnelly, 2007.
[xxii] National Audit Office, 2010.
[xxiii] See http://www.nuffieldfoundation.org/uk-outlier-upper-secondary-maths-education
[xxiv] Universities UK, 2012.
[xxv] Dillon et al., 2000.
[xxvi] CST, 2000.
[xxvii] Ipsos MORI, 2011.
[xxviii] Department for Culture Media and Sport, 2011; Ecsite-UK, 2008.
[xxix] OECD, 2012.
[xxx] Frontier Economics, 2009.