HOUSES OF PARLIAMENT
PARLIAMENTARY OFFICE OF SCIENCE & TECHNOLOGY

POSTNOTE

Number 430 March 2013

STEM education for 14-19 year olds

Science, Technology, Engineering and Mathematics (STEM) education plays a vital role in equipping young people with the knowledge and skills needed to participate in and contribute to society. This POSTnote reviews the current state of STEM education for 14-19 year olds in the UK, highlighting key challenges and ongoing policy reforms.

Overview

- There is a shortage of STEM skills in the UK workforce, with 42% of employers reporting difficulties recruiting STEM-proficient staff.[1]
- There is concern that a gap exists between what is provided by STEM education and what is required by industry.
- Some argue that this is being accentuated by a decline in aspects of educational standards in the 14-19 phase.
- A balance is needed between academically trained scientists and engineers, and highly-skilled but vocationally-oriented individuals.
- The positive attitudes of young people towards STEM often do not translate into career aspirations, and efforts to widen participation have had mixed success.
- A shortage of high-quality specialist teachers is exacerbating these challenges.

Background

In its 2011 report, *The Plan for Growth*, the Government pronounced education "the foundation of future economic success".[2] It highlighted the importance of science and mathematics and the key role to be played by STEM in driving innovation, growth and economic recovery. STEM education can also fulfil a wider function, providing people with the scientific literacy and numerical understanding needed for informed debate and decision-making. Key issues include the need to increase and widen participation, maintain quality, and ensure that educational outcomes are suited to society's needs. In light of planned changes to the UK's education systems, this note explores the debate over how these challenges can be tackled.

Study Options and Planned Reforms

There are many options open to young people wishing to study STEM in the UK, with minor variations currently across England, Wales and Northern Ireland, and more significant differences in Scotland.

Traditional Qualifications

England

In England, traditional STEM education from 14-16 is currently dominated by the mandatory study of science and mathematics, with little specific coverage of technology or engineering. Most pupils work towards one GCSE in mathematics, and one, two or three GCSEs in science (Box 1). For 17-18 year olds continuing into higher education, the most common route is through AS and A levels. At any given time roughly 40% of 17 year olds in England are thought to be entered on AS/A level courses, with around 30% studying biology, chemistry, physics or mathematics.[3]

Key reforms in recent years include the introduction of the English Baccalaureate or EBacc (Box 2) and of several new models of school, including academies, free schools and university technical colleges (Box 5). In addition a number of reforms are proposed or in planning, as outlined below.

- **The National Curriculum Review:** proposes revised programmes of study to "increase rigour" in English, mathematics and the sciences, while "slimming down" the curriculum in other subjects. It also proposes changes to league tables (Box 1) and replacement of the ICT curriculum with a new computing one.[4]
- **A level reform:** the Government plans to make the AS level a standalone qualification, and introduce a system of assessment with exams being taken only at course-end.
- **GCSE reform:** plans to replace GCSEs in EBacc subjects with 'English Baccalaureate Certificates' were withdrawn in early 2013.[5] The Government now plans to reform GCSEs to include more challenging content and rigorous assessment, with teaching from 2015 onwards.

Box 1. GCSE Science in England, Wales and Northern Ireland

The following GCSE science options are currently available:

- **GCSE Science ('Core')**: A single GCSE incorporating elements from across the sciences, intended to develop scientific literacy. Taken as a single qualification or alongside other science GCSEs.
- **GCSE Additional Science**: A single GCSE with a conceptual focus, intended to provide a foundation for AS level. Commonly taken alongside Core Science for the award of two GCSEs.
- **GCSE Additional Applied Science**: A single GCSE with a focus on the practical applications of science in industry. Can be taken alongside Core Science for the award of two GCSEs.
- **GCSE Biology/Chemistry/Physics:** Single science GCSEs, often referred to as "Triple Science" when taken in combination.

GCSEs in supplementary STEM subjects including statistics, electronics, astronomy and environmental and land-based science are also offered in some schools.

- **Increase in participation age**: mandatory participation in education or training will increase from age 16 to 17 in 2013, and to 18 in 2015.

Wales and Northern Ireland

To date, Wales and Northern Ireland have retained an education system similar in structure and content to that of England, with GCSEs and A levels forming the key qualifications.[6] However, the planned reforms in England, as well as in Wales and NI, will likely lead to increasing divergence in the future.

Scotland

In 2010, Scotland's new 'Curriculum for Excellence' came into effect, bringing about a number of changes impacting on STEM education for 14-19 year olds. These included:

- an increase in the freedom of schools and teachers to define both lesson content and assessment material
- extended course length, leading to a reduction in the number of qualifications taken by 14-16 year olds
- the withdrawal of several practically-oriented Higher qualifications, including biotechnology and geology.

Vocational Qualifications

In addition to GCSEs, 14-16 year olds across the UK have the option to work towards a number of 'equivalent', often more vocationally-oriented, qualifications (Box 3). In England, there are currently over 3,000 such qualifications, and their popularity has increased in recent years, rising from 15,000 pupils entered in 2004 to 575,000 in 2010. These are currently included in the calculation of school league tables and are accredited as being worth up to six GCSEs. However, from 2014 these equivalencies will be reduced, with only 125 qualifications continuing to qualify for league table inclusion.

In Scotland, a number of vocationally-oriented subjects are available through the National Qualification system. Highers are currently offered in subjects including engineering and environmental science. Other non-traditional qualifications such as SVQs and HND/HNCs are also available in Scotland.

Box 2. Performance Measures

The English Baccalaureate, or EBacc, is a performance measure introduced retrospectively by the Department for Education (DfE) in January 2011. Its aim is to increase the number of pupils receiving a broad education in core academic subjects, while providing a more accurate view of the overall academic performance of schools. The EBacc is currently awarded to pupils achieving six or more A*-C grade GCSEs in English, mathematics, science, a language (other than English) and a humanity – a combination taken by 25% of pupils in 2011/12. To complete the science element, students must attain A*-C grades in Core and Additional Science, or have taken all three sciences and achieved at least two A*-C grades. From 2014 Computer Science will be added to the list of science options. In February 2013 the Government also proposed two additional performance measures for schools:

- the percentage of pupils in each school obtaining grade A*-C in English and Mathematics
- an average point score across eight subjects, which shows how much progress a student has made between Key Stage 2 (7-11) and Key Stage 4 (14-16). As well as English, mathematics and at least three EBacc subjects, these can include 'high value' arts, academic and vocational qualifications which qualify for inclusion.[7]

Challenges in STEM education

Research indicates that there are currently 5.8 million people employed in STEM-based occupations in the UK – equivalent to 20% of the total workforce. However, there are limited data available on the supply and demand of individuals with STEM skills to the UK workforce, and ambiguity over the skills desired by industry.[1] This has led to a lack of clarity over what STEM education should be trying to achieve in order to satisfy employers' needs.

Historically, concerns have focused on a perceived shortage of university graduates, particularly in the physical sciences. However, there are now increasing concerns over the scarcity of young people pursuing more practically-oriented routes into STEM.[1,4] In 2012 the Confederation of British Industry (CBI) reported that 42% of employers currently experience difficulties in recruiting STEM-proficient staff, at all levels of expertise, from apprentices to post-graduates. Over a third of employers also felt that the content of qualifications held by applicants for STEM roles did not equip them adequately for work.[1]

It is widely agreed that key challenges in STEM education include the need to:

- increase and widen participation in STEM education
- ensure the quality of STEM education, and its suitability to employer's needs.

It should be noted, however, that in some cases a lack of high-quality data prevents definitive conclusions from being drawn in the field of STEM education. This is particularly true for policy reforms, as these are often introduced in quick succession, making it difficult to monitor cause and effect. Moreover several of the reforms are either still in planning or have been implemented very recently, so there is limited detailed analysis, or information on impact, available at the present time.

Box 3. Non-Traditional Options for 14-19 Year olds in the UK
As well as traditional academic qualifications, several non-traditional options are also currently available in the UK. These include:
- Applied GCE A/AS-levels: School-taught but with practical focus, these are intended to provide a broad introduction to a vocational area. STEM options include Applied Science and Engineering.
- 14-19 Diploma (Foundation/Higher/Advanced): School or college-taught qualifications combining general and vocational learning, intended to provide a route into employment or further education. The future of the current Engineering Diploma is uncertain; plans for a Science Diploma were cancelled in 2010.
- OCR Nationals/BTECs/HND/HNCs/Vocationally Related Qualifications: Work-related qualifications taught mostly in schools or colleges, intended mainly as preparation for a vocation but also enabling access to some forms of higher education.
- National Vocational Qualifications (NVQs)/Scottish Vocational Qualifications (SVQs): Vocational competency-based qualifications delivered primarily in the workplace.
- Apprenticeships: Work-based placements, popular with young people wishing to train for a vocation. There are thought to currently be over 30,000 under-19 STEM apprenticeships, primarily in engineering, with fewer positions available in other STEM fields.t

Participation in STEM education

Young Peoples' Attitudes to STEM
Evidence suggests that shortages in the number of young people pursuing STEM are not, for the most part, due to negative attitudes towards STEM. A recent study found that the majority of 10-14 year olds in England enjoyed and were interested in science. Nevertheless, less than 17% of these children aspired to a STEM career.[4] This mismatch between interest and aspiration has a number of possible causes. Evidence suggests that both children and parents often perceive science to be a subject suitable for only the most able pupils, leading many young people to feel that it is simply 'not for me'.[4] STEM-related careers are also narrowly perceived, with students often unaware of the transferability of STEM skills, and the range of careers that STEM can lead to (Box 4). These issues are particularly acute for families with a low level of 'science capital' (i.e. qualifications, knowledge, and connections with science).[8]

Widening Participation in STEM
The relationship between participation and attainment in STEM, and its link to social factors such as gender, ethnicity and socioeconomic status, is complex. However, some broad trends can be identified:[3]
- Up to age 16, boys and girls reach similar levels of attainment in science and mathematics, although girls tend to perform better than boys in many other subjects.
- At A level/Higher, significantly more girls than boys study biology, and significantly more boys than girls study physics, with roughly equal participation in chemistry.
- Students from poorer backgrounds tend to perform more weakly in STEM and other subjects, pre and post-16.
- Adjusting for socioeconomic status, there is a strong correlation with ethnicity, with Asian students often performing well in STEM subjects and Caribbean and White English students tending to perform more poorly.
- Overall, the strongest predictor of post-16 participation in STEM is prior attainment, with GCSE triple award students being the most likely to take STEM A levels.

Box 4. Careers Guidance and Work-Related Learning
In 2012 a statutory duty was placed on schools to secure access to independent careers guidance for pupils aged 14-16. It was expected that the requirement for independence would ensure that schools would source this guidance externally, thereby avoiding a potential conflict of interest between school and pupil. However, research suggests that some schools have focused instead on internal provision, with staff members delivering the majority of advice, supported by national online or telephone services. This has led to concerns about the quality and impartiality of such advice, particularly in the complex STEM field. Changes have also come into effect concerning school-led work experience. In 2012, the duty on schools to provide Year 11 pupils with two weeks of 'work-related learning' was repealed on the advice of the 2011 Wolf Report. Some STEM experts, however, are concerned that this will limit access to work experience, reducing careers awareness.

To date, attempts to widen participation in STEM have achieved mixed success (see also POSTnote 382 on Informal STEM Education). There has been much debate over the potential impact of the EBacc on participation in STEM subjects, but it is too early to draw conclusions. The data available are limited and the impact of new performance measures in England (Box 2) on participation is not yet known. In Scotland, while the new Curriculum for Excellence is intended to provide students with a broad educational grounding, there are fears that a reduction in the number of qualifications taken by 14-16 year olds may discourage pupils from studying all three sciences.

Quality and suitability of STEM education

The STEM 'Skills Gap'
In addition to concerns about participation, there is increasing consensus that the current education system fails to provide young people with the STEM skills and knowledge necessary to succeed in the workplace and at university.[1] This is a particular concern in engineering, where some argue that a lack of practical experience is compounded by the inadequate mathematical grounding provided in schools. A 2012 House of Lords inquiry found that "the level at which [mathematics] is taught does not meet the requirements needed to study STEM at undergraduate level", and recommended that continued mathematical study remain compulsory post-16;a proposal widely supported in the STEM community and under consideration by DfE.[9]

There has been widespread debate about the inadequacy of current ICT curricula to equip pupils with the computing skills they need and the lack of incentive for schools to offer more rigorous Computer Science GCSEs. In response, the ICT curriculum will be replaced with a Computer Science curriculum with a much greater emphasis on computational thinking and practical programming, designed with expert advice from the Royal Academy of Engineering and BCS, the Chartered Institute for IT. In addition, Computer Science will be one of four science subjects in the EBacc from 2014 (Box 2).[4,7,10]

Declining Standards
There is a widespread perception that there has been a decline in the rigour of assessment in the education system

in recent years. Between 1988 and 2011 the proportion of GCSE entries awarded A/A* grades increased each consecutive year, from 8% in 1988 to 23% in 2011 (declining slightly to 22% in 2012). Science saw some of the largest grade improvements, with the overall A*-C pass rate for biology rising from 60% in 1993 to 93% in 2011, and from 46% to 87% for core and additional science.[11]

There are a number of potential influential factors, such as changes in teaching standards, school facilities or pupil attitudes. The House of Commons Education Committee has suggested that this trend has arisen partly because of competition between England's awarding bodies. This is supported by Ofqual's findings that changes to the structure and content of GCSE and A level papers in biology, chemistry and mathematics led to these qualifications becoming less demanding between 2003 and 2010. Several of DfE's reforms are targeted at increasing the rigour of the assessment system for 14-19 year olds.

Balance of Academic and Vocational Qualifications

Despite these concerns about standards, traditional STEM subjects are often considered especially challenging by students. A statistical analysis of the relative difficulty of different subjects conducted by researchers at Durham University concluded that STEM subjects are "without exception among the hardest of all A levels".[12] It is considered likely that some students reject these 'hard' subjects in favour of maximising university admission points by attaining higher grades in other subjects.

While vocationally-oriented STEM qualifications are often considered less challenging and therefore more attractive than their traditional counterparts, there is concern over their status. UCAS, the University and Colleges Admissions Service, treats many of these qualifications favourably, awarding the same number of points, for example, to both applied and traditional A levels. However, universities and employers tend to hold them in lower regard, often requiring very high grades or supplementary qualifications as prerequisites for entry, or discounting them altogether. Some educational experts are therefore concerned that students may be investing resources in obtaining qualifications of limited value. The inclusion of 'high value' vocational qualifications in the new performance measures (Box 2) is highly relevant to this debate, but it is too early to speculate on impact. It is widely recognised that there is a need for an alternative route into STEM for those who are more practically-oriented, and the introduction of University Technical Colleges has therefore been welcomed[7] (Box 5). There are also concerns that a more exam-based assessment system might reduce focus on practical work, and is ill-suited to applied topics such as statistics and engineering, which are often challenging to examine.

Stem Teacher Availability and Expertise

The shortage of specialist STEM teachers, particularly in physics, chemistry, mathematics and computer science, is a long-standing concern. In 2010, the Institute of Physics (IoP) estimated that at least 500 English state schools did not employ a specialist physics teacher. While there is debate over the impact of non-specialist teaching, it has been shown that in schools with no physics specialists, fewer students go on to study physics A level. Experts fear that until this issue is resolved, other challenges in STEM education are likely to persist. To tackle this problem, DfE now offers bursaries for PGCE candidates specialising in physics, chemistry and mathematics. The IoP and the Royal Society of Chemistry have made teaching scholarships available to science graduates, leading to an increase in recruitment in recent months. However, STEM teacher quality remains an issue. One effort to boost this is DfE's new policy to reject applications for PGCE funding from those with third class degrees, and to offer reduced financial support to those with 2:2s. Some experts, however, argue that degree class may not be a good indicator of teacher quality, and that these reforms may exacerbate shortages in some STEM subjects.

Box 5. Schools Reform in England

A number of new school models have recently been introduced in England, based on a common theme of greater autonomy and freedom from public control. These include:

- **Academies:** Publicly-funded schools granted significant freedom over curriculum delivery and administration. Over 50% of all English maintained schools have now achieved academy status.
- **University Technical Colleges (UTCs)**: Industry or university-sponsored technical academies intended primarily to provide 14-19 year olds with the practical skills needed to meet the needs of STEM employers. Five UTCs are open with a further 26 planned.
- **Studio Schools**: State schools offering both academic and vocational qualifications, taught in a practical and project-based way intended to develop core skills and employability. By 2013, 30 are expected to be open.
- **Free Schools**: Independent, not-for-profit, state-funded schools, set up by a variety of groups with the approval of DfE. Seventy-nine free schools were open as of September 2012, including one STEM-focused school, with another 102 schools granted approval.

UTCs in particular have been welcomed in the STEM community, although there are concerns that freedom from the national curriculum may lead to a reduced focus on STEM in some schools, particularly faith-based free schools. DfE maintains that all schools will be held to the same Ofsted-assured standards, and will be required to provide students with a 'broad and balanced' curriculum.

Endnotes

1 CBI , Education and skills survey, 2012
2 HM Treasury, The plan for growth, March 2011
3 Royal Society, State of the Nation: Science and mathematics education, 2012
4 DfE, Reform of the National Curriculum in England, 2013
5 House of Commons Education Committee, From GCSEs to EBCs: the Government's proposals for reform, 2013
6 Department for Education (Northern Ireland), Council for the Curriculum Examinations & Assessment, GCSE and GCE review; Welsh Government, review of qualifications for 14-19 year olds in Wales, 2012
7 DfE, Secondary School Accountability Consultation, 2013
8 Archer, The case for early education about STEM careers, Science Council, 2012
9 House of Lords Science and Technology Committee, Higher education in Science, Technology, Engineering and Maths, 2012
10 Royal Society, Shut Down or Restart?, 2012 ; NESTA, Next Gen., 2011 ; BCS, The case for Computer Science as an option in the EBacc, 2012
11 Burn-Murdoch, How have GCSE pass rates changed over the exams' 25 year history? Guardian datablog, 2012
12 Coe, Relative difficulty of examinations in different subjects, 2008

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology.
POST is grateful to Victoria Charlton for researching this briefing, and to all contributors and reviewers. For more information, please contact Dr Chandrika Nath. POST also thanks Anders Aufderhorst-Roberts for his research, and the EPSRC for funding his fellowship.