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Campaign for Science and Engineering in the UK

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CaSE Working Paper

EDUCATION & SKILLS

INTRODUCTION

Everyone needs to achieve the level of science and mathematical understanding necessary to participate and thrive in the modern world. The UK also needs millions of people with a much higher level of these skills in the workforce.

- Over the last decade the number of people graduating in science, engineering and related subjects has increased but this has been driven by rapid expansion of certain subjects like sports science and psychology. The proportion of all graduates taking the core disciplines of physics, biology, chemistry, maths, engineering and technology is just 13%.[1]
- The number of UK PhDs is stable in the natural sciences and rising in engineering, although its market share is dropping in all these subjects.
- Over nine out of ten businesses employ people with science, technology, engineering and mathematical skills, but two thirds of all employers report difficulty recruiting enough of these workers, particularly at the graduate and postgraduate level.[2]

Action: **More people need to be educated in the key disciplines of science, mathematics and engineering through increasing student opportunity and interest. People with these skills should be encouraged to use them in the UK workforce.**

This working paper focuses on the English education system. Improving education in schools and colleges should promote interest in these subjects at universities, eventually enhancing the skills available for research and its development (See CaSE working paper on Research Funding). Science and mathematics skills are also critical for delivering evidence-based policies (see CaSE working paper on Science and Engineering in Government).

PRIMARY SCHOOLS

Primary School Teaching

The recent Williams review estimated that just 3,000 out of 17,000 English primary schools had a teacher skilled in mathematics and highlighted the importance of background knowledge for quality teaching.[3] The government accepted that all primary schools should have a mathematics specialist with deep mathematical subject and

pedagogical knowledge, either from graduate studies or appropriate professional development training. This provision should be extended to science.

Action: **All primary schools should have both a mathematics and a science specialist with relevant graduate level qualifications or additional training.[4]**

Primary School Testing

Preparing for tests at the end of primary school inhibits students' enjoyment, with teachers relying on worksheets rather than student inquiry.[5] Science will now be teacher rather than nationally assessed at the end of primary school - this is a better and cheaper option, as long as science continues to be prioritised. Unfortunately, mathematics is still assessed through national assessment.

Action: **Mathematics in primary schools should, like science, be teacher-assessed.**

SECONDARY SCHOOLS & FURTHER EDUCATION

Subject Options

Students start to take different options in science in England at 14 years of age. Although taking two combined science GCSEs can lead to science A levels, students that study three separate biology, physics and chemistry GCSEs (triple science) are more likely to study and do well later at science A levels; unfortunately, only a tenth of students do so.[6,7,8] The government had a target for all high-achieving pupils to be entitled to study triple science by September 2008, although not necessarily in their own schools, and for all specialist science schools to offer triple science.[9]

In 2008, only 32% of maintained schools entered students into triple science - it is not known how many science specialist schools did so, but it could not be more than 72%.[10] It is estimated that about half of schools entered students into triple science in 2009 and up to 70% may now offer it.[11]

There is serious inequality in triple science provision; while independent schools accounted for 9% of all GCSE entries in 2009, they made 18% of entries in triple science and while grammar schools accounted for 6.5% of all entries they made 17% of those in triple science.[12] There are worrying numbers of schools now offering students BTECs, rather than science GCSEs. This obviously limits student choice and may affect progression to science A levels. Some vocational qualifications like OCR Nationals and BTECS are often perceived to be over-valued in the league tables as equivalent to four GCSEs and in 2007 there have been very steep recent increases in their uptake.

Action: **The opportunity to study separate biology, physics and chemistry GCSEs should be extended to all interested students through a new statutory duty.**

The development of a pair of mathematics GCSEs should enhance students

understanding and enjoyment of the subject and better reflect the amount of effort that they put into their studies. It is to be welcomed.

Action: **Introduction of the new pair of mathematics GCSEs, intended for all students, should continue.**

Various factors will have contributed to the declining student interest in science and mathematics A levels including teaching (discussed in the following section). Although numbers have now stabilised or picked up, they are still all at lower levels than they were ten years ago: 6.5% of all students took biology A level in 2008 (down from 7.2% in 1997), 4.9% took chemistry (5.5% in 1997), 3.3% took physics (4.3% in 1997), 7.8% took mathematics (8.5% in 1997).[13] The only gain has been in further mathematics, that over 1% of students now take – this followed a concerted campaign by the mathematics community and shows that what was perhaps perceived as an inevitable decline could be reversed with the right strategies.

The under-representation of certain groups of students and workers in science, mathematics, and engineering, often starts with A level choice. For instance, only 3.6% of girls take physics A level compared with 16.5% of boys, but the government target of 35,000 students to take physics A level by 2014 is not broken down by gender.

Action: **Government targets for increasing uptake should be refined to enhance equality. Strategies to improve uptake may be most beneficial and cost-effective if they are targeted at under-represented groups.**

Practical work and the teaching of scientific inquiry are essential elements of a science and engineering education. They are also highly motivating and improve student performance.[14] But many teachers have reported reducing the quantity and variety of practical work for a number of reasons including costs.[15,16] Any tightening of the education budget must not squeeze out practical experience.

Action: **Practical work should make up a large part of science and engineering all the way through schooling.**

It is harder to achieve high grades in some A levels, including the sciences and mathematics, than others and students are aware of this.[17] As students and their schools and colleges are typically judged on points reflecting their grades, easier subjects predominate. This situation can and should be addressed:

- All examinations could be marked with the same severity.
- More points could be awarded to subjects it is harder to get high grades in.[18]
- More information could be included in league tables so that schools are judged on subjects and qualifications as well as grades.
- Universities and employers could and should be clearer about which A levels they highly value.[19]

Students often base their subject choices on misconceptions. Careers advice should start early in school and draw from a diverse range of role models. Recent initiatives to improve careers advice, including the development of a database to provide students with more

coherent and comprehensive information, are to be welcomed. Investing in careers advice should result in a workforce better matched to market needs.

Action: **Factors that discourage students and schools from more rigourous subjects like science and mathematics should be eliminated or counteracted. Students need to be better informed of how their choices may restrict or enhance access to later career or educational opportunities.**

Competition among awarding bodies has contributed to a confusing range of qualifications at 14-19. The addition of the engineering diploma has been generally well received but the planned science diploma remains controversial, not least because of a lack of clarity of its role. Competition among awarding bodies also discourages them from setting rigourous exams, given that students and their schools and colleges want to achieve the best grades possible. Falling standards and a reduction in mathematical content are perceived in many subjects, and data support such perceptions.[20] Indeed, OfQual recently took urgent steps to improve single science GCSE.[21] Limiting the number of modular assessments and the number resits of each allowed will also reduce teaching-to-test, time-table disruption and costs.

Action: **The range of academic and vocational qualifications at 14-19 years should be clarified and rationalised – almost all need more mathematical content, especially the sciences.**

Further education colleges account for 24% of A level entries in mathematics, 25% in the sciences and a wide range of vocational qualifications, producing almost half of all entrants to higher education. Vocational routes open up opportunities for students not attracted to classroom based learning and provide a vital source of skilled workers such as technicians. Vocational science and engineering courses are funded at marginal levels insufficient to cover equipment and delivery costs.[22,23] This deters colleges from encouraging their uptake compared to other subjects and important but costly vocational work is often reduced. The proposed provision of technical colleges, which must be funded to ensure quality delivery of technical vocational qualifications, is to be welcomed.

Action: **Further education and vocational routes into science and engineering need to be properly valued and funded.**

Apprenticeships

Apprenticeships are essential to the upskilling of the UK's current and future workforce, providing work-based, sector specific qualifications. New collaborations to enable smaller companies to provide training and resources are effective and should be expanded. During the economic downturn, it is vital that the government support employers in their provision of apprenticeship places.

Secondary School Teaching

The quality of science teaching relates to teachers' qualifications, with a better match improving standards and achievement.[24,25] Unfortunately, many schools have

difficulty recruiting teachers specialised in the sciences: [26, 27]

- A quarter of maintained 11-16 schools lack a physics specialist.
- In 2007, only 58% of general science teachers had a science degree.
- Specialist teachers are less likely to work in lower attaining schools or in socially deprived areas.
- In mathematics, in 2007, 75% of grammar school lessons were taught by teachers with a mathematics degree, compared with 47% of lessons in comprehensives to age 16 and 58% of comprehensives to age 18.

While the recession has boosted numbers entering teacher training, it will take much more than this to fix the situation – it has been estimated that a sustained recruitment of 1000 trainees in physics and 3000 in mathematics would be needed to significantly improve the situation.[28] Routes enabling teachers to develop a specialism must continue to be supported - over the past 3 years, 25% of entrants to physics teacher training came through such additional training. New plans for professionalisation of the teaching workforce should include subject specific training.

Action: **All secondary schools should have teachers with specialist knowledge in each of biology, physics and chemistry and in mathematics. New targets for training teachers into each of the sciences (rather than grouping them under science) should be retained. The pool of teachers available can be expanded by providing specialist training.**

There is little competition for science and mathematics teacher training and high drop-out during and after the courses.[29] Only half of science and mathematics teachers are still in the profession 5 years after graduating.[30] Teacher retention should improve with more support staff and especially technicians given that they have been consistently cited by teachers as improving workload, job satisfaction and stress levels.[31]

Action: **The low retention of secondary science and mathematics teachers produces shortages and high recruitment and training costs. Evidence suggests that retention would be improved with more support staff and technicians – it would be a false economy to cut them.**

Recruitment and retention could be improved by market forces by increasing the value of specialist teachers to head-teachers, through including specialist teacher provision in measures of school accountability, such as the school report card. All schools applying or re-applying for specialist status in science related subjects should meet these requirements. Head-teachers do have flexibility in salaries, they can directly recruit trainees through employment based routes, and they can improve provision of support staff and access to continuing professional development. Such a strategy should also help draw specialist teachers to schools where they are most needed.

Action: **All schools applying or re-applying for specialist status in science related subjects have a specialist in every science. New specialist teachers should be targeted to schools where they are most needed.**

TEACHING IN UNIVERSITIES

The strategic importance of producing more science, technology, engineering and mathematics graduates is clear. But the market operating in student choice of university subject is not delivering enough graduates in these disciplines – more direct steps need to be taken to increase their uptake. It may be worthwhile targeting university bursaries into strategically important subjects, these could be made more cost-effective by delivering them to high-achieving students who would not typically progress to higher education.[32]

The financial savings from living at home have already affected students' choices of where to study.[33] It seems inevitable that variable subject fees would affect their choice of what to study and must not work against the need to increase uptake of strategic subjects. Student debt also discourages new graduates from lower paid careers that are valuable to the UK, like teaching and further study and research.

Action: **If variable student fees are introduced for different courses they must not discourage students from studying the subjects that are vital to the UK's future.**

Expensive practical subjects used to receive funding at twice the rate of library-based subjects but in 2004, the ratio was reduced to 1.7. Financial problems were accentuated by increased concentration of research funding. After a number of closures of chemistry and physics departments, additional support was made available for strategically important subjects that are also vulnerable. Under-funding not only reduces the quality of the future workforce but may also risk the attractiveness of a UK university education to overseas students.

Action: **The funding of teaching at universities must increase to reflect the true cost of teaching the more expensive science and engineering subjects. Until data on the cost of teaching these subjects are gathered, the funding formula should be returned to 2.**

Overseas Students & Academics

Some university courses depend on international students to fill up places, more than 60% of higher degree students and 27% of academic appointments were from overseas in 2007. This makes them highly vulnerable to factors beyond their control that might rapidly change migration patterns. The UK gains over £5 billion in fees and living costs from international students and £2 billion from students who stay on after graduating, along with wide-ranging non-monetary benefits.[34,35,36] While numbers of international students are increasing, the UK's market share is decreasing. There are ongoing problems with the new points based visa system including the level of bureaucracy and the burden to prove financing up-front for many applicants.

Action: **The visa system should not lessen the UK's attractiveness to overseas students and academics.**

RESEARCH SKILLS

The availability of researchers in the workforce is falling in the UK but rising in other comparable countries.[37] As well as improving education, more must be done to keep qualified researchers active and to make sure that the UK is an internationally attractive place to work in research.

Action: **Although there have been improvements, problems with research careers persist including short-term contracts, difficulty moving between public research and industry and inflexible work practices.**

Under-Represented Groups

Distinct groups of people are under-represented in some areas of science and engineering like women, people from certain ethnic minority groups, and disabled people. This represents an enormous loss of potential, not just from the sheer numbers of scientists and engineers there could be, but also from a restriction on the range of perspectives that can be used to enhance innovation.

- Only 25% of women with science, technology, engineering and mathematics degrees are employed in their subject area, compared with 40% of men, at an estimated to cost of £15-23 billion.[38,39]
- Black Carribbean students are not entered into higher tier science and mathematics papers at appropriate rates and they are disproportionately encouraged onto vocational courses.[40,41]
- About 6% of the UK workforce are disabled, but just 4% work in science and engineering.

Diversity is only slowly being improved from interventions aiming at bringing more under-represented groups into science and engineering education and work. It also needs to be implemented at higher levels to pull others up.[42] Belonging to an under-represented group is a disadvantage in itself - partly because of the shortage of role models, mentors, and support networks and also because these groups may be poorly represented on influential committees, governing bodies, interview panels, etc.

Action: **Resources to enhance the representation of women should be sustained and similar resources should be developed for other under-represented groups, including some ethnic minority groups and disabled scientists and engineers.**

Overseas Workers

The UK is one of the top destinations for international scientists and engineers. The presence of an international workforce is critical for industry to choose to locate in the UK, or for those currently here, to stay: 86% of large firms recruit scientists, technologists or engineers from overseas, not just because of skills shortages, but also to enhance their internationalism.[43] The increasing numbers of papers with UK and international authors, rising from 33% in 1999 to 47% in 2007, have higher citation rates than papers just by UK authors.[44] The points-based visa system should better accommodate researchers; for instance, salary assessments fail to consider the relatively

low pay of academia compared with other sectors. It also needs to support a short-term free-flow of scientists and engineers to facilitate international collaborations.

It is much easier for immigrants to work in the UK if they have a job on the shortage occupation list. This list is recommended by the Migration Advisory Committee (MAC) and includes many areas of science and engineering. The work of the MAC should be harmonized with those bodies supporting strategic subjects and it should be considered whether primary science and mathematics teachers should be included in the list (secondary level teachers already are). Immigration may be welcomed for its inherent value, but it is not an appropriate long-term solution to skills shortages and more should be done to train students in these areas in the UK.

Action: **Overseas scientists and engineers should be valued and welcomed for the diversity and international opportunities that they bring.**

Further Information

This is one of three CaSE working papers developed with input from CaSE members and other collaborators in the run-up to the general election 2010. The others cover *Science & Engineering in Government* and *Research Funding*.

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[1] *Emerging stronger: the value of education and skills in turbulent times.* CBI/Nord Anglia, 2009.
[2] *Emerging stronger: the value of education and skills in turbulent times*. CBI/Nord Anglia, 2009.
[3] Independent Review of Mathematics Teaching in Early Years Settings and Primary Schools, Williams, June 2008.
[4] Ideally this would apply to all schools, although it may not be realistic for those with a very small staff.
[5] Success in science, Ofsted, June 2008.
[6] Qualitative data from Ofsted suggests that students who study triple science are more likely to continue studying science at A level and beyond*. Success in science, Ofsted, June 2008.*
[7] More specific analysis found that the odds of getting an A or B grade at chemistry A-level were increased by 76% for pupils who took triple science rather than two combined sciences. *Science and Innovation Investment Framework 2004-2014: Next Steps – 2006 budget.*
[8] Studying A level physics was correlated with haven taken physics GCSE. *Specialist Science Schools, Smithers & Robinson,* Centre for Education and Employment Research , January 2009*.*
[9] *Science and Innovation Investment Framework 2004-2014: Next Steps*.
[10] Department of Children, Schools and Families & parliamentary question, Mr. Gibb, 10 June 2009, 277957
[11] Communication form DCSF
[12] Joint Council for Qualifications, Data for Centre Types and Regions, GCSE, Applied GCSE, ELC 2009.
[13] *Science Fiction? Uncovering the real level of science skill at school and university*. Policy Exchange, October 2009.
[14] *Success in science,* Ofsted, June 2008.
[15] *Survey on Secondary School Science Teachers,* Save British Science 2004
[16] *Survey on Scottish Secondary School Science,* Save British Science 2004
[17] Coe et al, (2008). *Relative Difficulty of Examinations in Different Subjects.* The Curriculum, Evaluation and Management (CEM) Centre, Durham University.

[18] *Higher UCAS points for STEM.* CaSE Briefing Proposal, July 2008.
[19] In fact, Cambridge University highlights the fact that mathematics and science A levels "help keep your higher education options open". *Subject Matters. Post-16 Subject Choices*. University of Cambridge, 2007.
[20] *The Five-Decade Challenge. A wake-up call for UK science education?* Royal Society of Chemistry, November 2008
[21] *GCSE science monitoring report*, 2007-2008, OfQual, March 2009.
[22] *Understanding the Needs of FE Engineering & Technology Departments,* New Engineering Foundation, November 2006.
[23] *New Engineering Foundation Manifesto*, 2009.
[24] *Success in science*, Ofsted, June 2008.
[25] *Physics in Schools and Colleges: teacher deployment and student outcomes.* Smithers & Robinson, The Centre for Education and Employment Research, University of Buckingham, 2005.
[26] *Mathematics and Science in Secondary Schools. The Deployment of Teachers and Support Staff to Deliver the Curriculum.* National Foundation for Educational Research & DfES, 2006.
[27] *Secondary School Curriculum and Staffing Survey 2007,* June 2008.
[28] *State of the Nation report on Science and Mathematics' teaching*, Royal Society, December 2007.
[29] *The Good Teacher Training Guide, 2007-8.* Smithers & Robinson, University of Buckingham, July 2009.
[30] *State of the Nation report on Science and Mathematics' teaching*, Royal Society, December 2007.
[31] *Mathematics and Science in Secondary Schools. The Deployment of Teachers and Support Staff to Deliver the Curriculum.* National Foundation for Educational Research & DfES, 2006.
[32] *STEM Diversity Bursaries*. CaSE Briefing Proposal, July 2008
[33] Davies, et al. (2008). *Knowing Where to Study? Fees, Bursaries and Fair Access*. Institute for Educational Policy Research, Staffordshire University, UK, & The Sutton Trust.
[34] *Higher Ambitions. The future of universities in a knowledge economy*, BIS November 2009.
[35] *The Economic costs and Benefits of International Students*, Vickers, & Bekhradnia, 2007.
[36] *International Excellence: Valuing International Scientists and Engineers*, CaSE Policy Report, November 2008.
[37] *Performance of the UK Research Base*, EvidenceLtd for BIS, 2009
[38] *Maximising Returns to SET Careers*. DTI, 2002.
[39] *Towards a Fairer Future*. DTI, 2006.
[40] *Count me in! Gender and minority ethnic attainment in school science*. Frost, Reiss, & Frost, School Science Review, 2005, 86(316).
[41] *Minority Ethnic Pupils in the Longitudinal Study of Young People in England*. Strand, 2007.
[42] *Delivering Diversity: Making Science and Engineering Accessible to All*, CaSE Policy Report, May 2008.
[43] *Emerging stronger: the value of education and skills in turbulent times*. CBI/Nord Anglia, 2009.
[44] *Performance of the UK Research Base*, EvidenceLtd for BIS, 2009.