

STEM EDUCATION
Text of a letter to the Prime Minister

11 July 2012

We share your aspiration to an excellent science, technology, engineering and maths (STEM) education system that produces our future scientists and engineers, and equips the public to understand emerging technologies. This is critical to our future economic growth: the UK workforce's skills in the STEM area will determine our ability to generate ideas and to translate these into innovative products and services.

If we are to achieve this excellence across the whole range of educational provision, we need an integrated approach to STEM from ages 4 to 24 covering school, further education and training, and university. This can only be achieved with effective work across a number of government departments and agendas. We recognise that the government has protected science funding at HE level. Schools are particularly critical in the way that they determine students' most formative experiences and significant decisions. Currently, our national school STEM education performance is only middling against key comparator nations, and weaker when compared with major emerging economies. We have therefore focused on this aspect in this letter.

We welcome your Government's focus on raising the standards of examinations to assess in-depth analytical thought more effectively. We are particularly pleased to see a focus on the importance of maths across the curriculum; we especially welcome the focus on the primary sector and the proposed development of more opportunities to study maths post-16, as well as improvements in the computing curriculum.

New incentives aimed at recruiting high performing maths, physics and chemistry graduates into teacher training should alleviate teacher shortages in these subjects as well as raising the status of the profession, complementing the way in which TeachFirst has presented teaching as a challenging opportunity for exceptional graduates.

Indicators show that the profile of science education is steadily improving with most secondary schools offering the full range of physics, chemistry and biology GCSEs, increasing participation in post-16 science, and preliminary evidence that physical science, mathematics and engineering university applications are holding up well despite an overall drop in applications. We welcome your Government's contributions to these improvements.

But we think there are a number of areas which will further help with implementing this agenda.

There have been many good reports published recently on the subject, and we have drawn on these in preparing this letter. A review of their key themes, which are summarised briefly in the Annex, is a good starting point. They emphasise what might be represented as a core “triangle” of excellence, centred on good curriculum, testing, and teaching practice. Diverse access to STEM, and the quality of careers advice are also important. Finally, a strong governance and accountability framework is essential if this is to be implemented.

Areas needing special attention

Curricula: Observational and experimental science learning needs to be better valued and rewarded in assessments, for its ability to instil fundamental reasoning, analytical and quantitative skills, as well as the practical precision vital to future scientists and technicians, and its ability to motivate students. Difficulties in assessment and limited emphasis on wider skills development may have diminished practical experiences for students, alongside poor confidence amongst non-specialist teachers.

Teaching: Inspirational teaching is vital. Science-specific Continuing Professional Development (CPD) enables upskilling of the current teaching workforce. CPD is vital in the sciences because there is insufficient time in initial teacher training to cover all of the subject-specific content and pedagogical knowledge necessary to teach all three sciences up to age 16, as is typically required of secondary science teachers; in any case, scientific knowledge is always progressing. High quality programmes developed by the National Network of Science Learning Centres have proven impact on teachers and students but school culture needs to shift to one in which subject-specific CPD is provided for new and established science teachers as a matter of course.

Primary science needs to be given more attention. A shortage of specialist expertise has persisted in this sector, with only 3% and 2% of primary teachers holding initial degrees and teacher qualifications in science and mathematics respectively. The removal of science SATs at the end of Key Stage 2 has liberated teachers from teaching-to-test but may have also contributed to a perceived fall in the status of primary science among teachers. We welcome DfE’s proposals for new training routes for primary science specialists, but impact needs to be achieved quickly and could be supplemented by CPD for current primary science coordinators.

Testing: England’s unusual system of competing awarding bodies has introduced perverse consequences that reward reduced rigour in testing. A mechanism is needed to better align examinations across boards, enabling standards to be raised without boards risking their market share, perhaps through working with subject expert groups. In addition, examination boards should not endorse text books that they themselves profit from.

Access to STEM: Participation and performance in STEM education closely reflect wider social inequalities. There are fewer opportunities to study triple science at GCSE, for instance, in deprived areas. We need to improve access across the system.

Careers advice: Careers information advice and guidance seems to be underplayed. We recognise the importance of schools’ new explicit responsibilities, but there is a risk that many schools will make only a limited response to new demands for which they have received no additional funding. It would be deeply regrettable if we were to put the

components of an excellent science education in place, only for students to miss out because they lack the information they need to guide them through it.

Governance: As schools become increasingly autonomous, high quality governance, already an area in need of improvement is ever more critical to enable change. Some schools have suffered from accountability systems that focus on a narrow definition of pupil and school success, and from governors lacking the right skills or ambitions. The Wellcome Trust has worked with others to develop three ways to improve school governance: the development of something akin to a Statement of Recommended Practice for governors, for example, to guide them on strategies for improvement and key areas of accountability; better access to data and training in their interpretation; and the recruitment of young, specially trained governors to help implement these suggestions and drive bold aspirations for school improvement (perhaps analogous to TeachFirst).

Recommendations

All of this comes down to a series of imperatives:

- an examination system that is structured to drive standards up, not down, and that promotes the use of diverse resources (including textbooks);
- better prioritisation of, and more value placed on, practical science;
- an embedding of subject-specific Continuous Professional Development for all teachers of science and mathematics;
- a guarantee that all students will receive quality careers advice; and
- every primary school to have, or at least have access to, a mathematics or science specialist teacher.

The quality of school governance will define the extent to which most of these goals can be realised.

The ability to implement change in the school sector is critical; this brings us to a final, critical imperative:

- the need to ensure that effective monitoring and reporting mechanisms are in place to ensure that this programme of change is carried out effectively.

In summary, integrated delivery, governance and accountability across all key areas (curriculum, teaching, testing, access to STEM, and careers advice and guidance) will be essential if the UK is to have an excellent school system which prepares pupils for careers in STEM. **We have been unable to identify a comprehensive roadmap for implementation of the Government's ambitions for STEM, indicating timelines and clear goals in the short term. There needs to be one.** It is essential if we are to see improvement on the timescale that is necessary. In the longer term, we would look for indicators that can be used to measure the extent of change.

We will want to return to these issues, and will be seeking to meet with DfE Ministers in relation to their plans for implementing the policies that will deliver on these imperatives and measure their effect. We hope to update you with our perspective on the way in which these are proceeding in a year's time. In the meantime, we would, of course, be happy to discuss further with you.

We are copying this letter to the Deputy Prime Minister, Michael Gove, Nick Gibb, David Willetts, and Sir Jeremy Heywood.

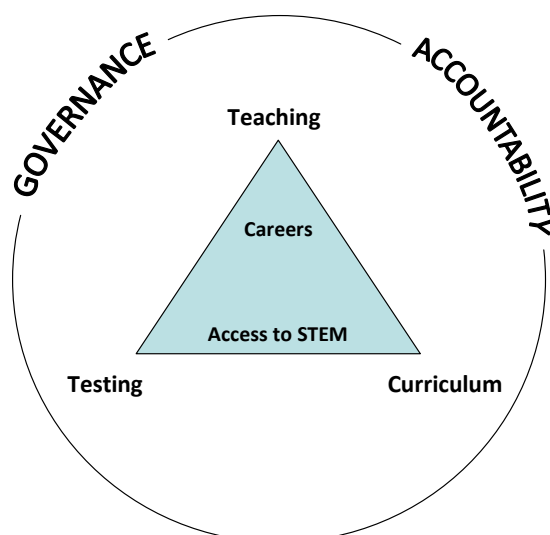
Signed:

Sir John Beddington
Professor Dame Nancy Rothwell

CST co-chairs

Annex: STEM education in schools: summary of recent reports

When we first considered your request for advice on this matter, we turned to the many good reports that have addressed the issues affecting STEM education in the UK in recent years. They have been remarkably consistent,ⁱ identifying a number of key issues. Three of these issues are absolutely critical to the early experiences that children have of the sciences and deserve to be brought out as a “triangle” formed by the elements of strong STEM education: teaching, testing and curriculum. Equally important from a social point of view are the quality of careers advice and of access to STEM opportunities across socio-economic groups. Governance and accountability are critical in setting the framework within which all these factors can be improved.



Curriculum and testing

The cornerstones of a school experience that will engender an early interest in mathematics and science is clear: access to well-informed, enthusiastic teaching staff, to inspiring practical work, to enrichment and “informal science”ⁱⁱⁱ activities, and a curriculum that is geared to nurturing a sense of wonder and excitement in these subjects, rather than serving the needs of the assessment system too narrowly.

The assessment system needs to work in such a way that students are incentivised to develop the breadth and depth of understanding that they need to really excel in STEM subjects.ⁱⁱⁱ This is not always easy to achieve. Childrens’ most formative experiences in determining their engagement with STEM start at Primary School, and narrow “teaching to the test” at Key Stage 2 was highlighted by one report as a factor that adversely affects students’ earliest experiences of science in the classroom.^{iv} One of the UK’s relative strengths is in the extent to which practical work has brought the classroom experience of science to life. There is a widespread view that its extent and quality is declining, however,

and that the provision of high quality enrichment and practical work is uneven between schools and areas.^v

The Reports often make the point that the assessment system has driven an increasingly formulaic approach to teaching.^{vi} The proliferation of qualifications between the ages of 16 and 19 has created a real lack of clarity for students, obscuring pathways into higher education and the workplace. One report addressed some of the issues underlying this: the proliferation of modular assessments at A level has worked against the understanding of key subjects in depth, and there is a widespread perception that competitive pressures between awarding bodies have affected grading standards. The practice of examination boards endorsing textbooks has also had an adverse impact on standards.^{vii}

Difficulties with the mathematics and computer science curricula have recently come into the spotlight. The central importance of mathematics as a discipline in its own right and as a key to a deeper grasp of many other subjects is widely recognised.^{viii} The absence of a requirement for compulsory mathematics in the UK in school curricula between ages 16 and 19 is unusual.^{ix} The handling of computer sciences has been particularly problematic. Non-specialist teachers are prevalent, reflecting a focus on superficial digital literacy rather than hands-on logic and programming skills. For students, this has meant a real lack of ambition in curriculum design, a poor image for the subject amongst other options, and very poor take up of computer science beyond GCSE.^x This has resulted in the absurd position where school-level computer science qualifications have not been recognised by some universities as sufficient preparation for degree-level studies in the subject.

Teachers and teaching

The reports all emphasise the importance of specialist teachers^{xi} especially in physics, chemistry and mathematics where significant shortages persist.^{xii} The Institute of Physics has calculated that we will need 1000 new physics graduates joining the teaching profession every year for 15 years to come if we are to meet the current gap in physics teaching.^{xiii} The data on the supply of specialists is also confusing, with basic definitions varying between surveys.^{xiv} The acute shortage of science and mathematics specialists in primary schools is particularly marked. One report highlighted that 3% and 2% of primary teachers held both initial degrees and teacher qualifications in science and mathematics respectively.^{xv} Responsibilities inevitably fall on the shoulders of generalists, who often do not have the expertise and confidence to make up for this shortfall.

If significant inroads into this gap are to be made, a number of alternatives to the usual approaches to recruitment need to be considered: for example non-standard routes for sourcing inspiring specialist teachers, opportunities for later career scientists (even retirees) to enter the profession, considering the competition in salary from alternative careers especially for those with significant mathematical skills.^{xvi} The importance of high quality and subject specific Initial Teacher Training and Continuous Professional Development (CPD) for STEM teachers, as a means of addressing some of the problems associated with the shortage of specialists is another consistent theme.^{xvii}

Careers

Decisions made at an early stage in life can impose severe restrictions on a student's choices and life outcomes at a later stage. The increasing complexity of pathways through the curriculum and qualification system has made the provision of expert careers advice more important than ever. The proliferation of vocational technology qualifications has also confused standards, complicating choices for students and employers alike.^{xviii} There have

been attempts to provide more clarity on their respective merits through employer surveys and other initiatives.^{xix}

It is crucial that they have access to the best informed advice, but provision is still uneven, and in practice advice is taken from a variety of sources, not all well informed.^{xx} Reports have highlighted the need for strong advice at key decision points, for instance in the final years of school^{xxi}, and the need for schools to tap into local and wider regional networks of expertise (including that of other schools) to give students access to the experience that they need in reaching informed careers decisions.^{xxii}

Access to STEM

The gender divide in the study of physical and biological sciences is well known, and there is evidence that differences in entry to, and attainment in, STEM subjects are related to wider inequalities of all kinds.^{xxiii} While the proportion of state secondary schools offering “triple science” at GCSE has increased significantly, it is less widely available in areas of higher deprivation.^{xxiv}

Governance and accountability

Finally, reports have also addressed structural and governance issues in schools.^{xxv} Schools without sixth forms, like primary schools, are less likely to attract specialist teachers: one report highlighted the lack of data on the way in which different pathways through the education system affects STEM attainment and opportunity for students.^{xxvi} Reflecting a developing policy of devolution of decision-making power to the educational front line, there has been increasing emphasis on the increasing need for excellent governance within schools to drive STEM improvement.^{xxvii}

i The recommendations of the main reports on STEM education from over a century are summarised in *Science and Mathematics Secondary Education for the 21st Century*, Report of the Science and Learning Expert Group, BIS, 2011. Key recent reports also include the Royal Society’s *State of the Nation* series, Report of the Science and Learning Expert Group, *Science and Mathematics Secondary Education for the 21st Century*, 2010, and *Report to the Secretary of State, DIUS, on Universities’ links with schools in STEM subjects*, led by Professors Julia Goodfellow and John Coyne, 2008.

ii The Wellcome Trust is commissioning a major review of informal learning, including the measurement of its impact, how it can be better linked to formal education, and how it can be better extended to deprived learners.

iii *Science and Mathematics Secondary Education for the 21st Century*, p. 43.

iv Royal Society, *Science and Mathematics Education, 5-14*, pp. 61-62

v *Science and Mathematics Secondary Education for the 21st Century*, pp. 57-60.

vi Royal Society, *Science and Mathematics Education 5-14*, pp. 4-5; *Science and Mathematics Secondary Education for the 21st Century*, recommendations 9 and 11, p42, p. 47.

vii *Science and Mathematics Secondary Education for the 21st Century*, p. 48.

viii *Science and Mathematics Secondary Education for the 21st Century*, recommendation 10 p. 47; *A world-class mathematics education for all our young people*, August 2011.

ix *Making Mathematics Count: Report of Professor Adrian Smith’s Inquiry into Post-14 Mathematics Education*, 2003, p.11

x Royal Society, *Shut Down or Restart? The Way Forward for Computing in UK Schools*, 2012.

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- xi Royal Society, *The UK's science and mathematics teaching workforce*, 2007, p. 17.
- xii SCORE, *Subject Specialist Teaching in the Sciences: Definitions, Target and Data*, 2011, p. 1.
- xiii Institute of Physics briefing note, September 2010.
- xiv Royal Society, *The UK's science and mathematics teaching workforce*, 2007, p. 10.
- xv Royal Society, *Science and Mathematics Education*, 5-14, p. 36. SCORE, *Subject Specialist Teaching in the Sciences: Definitions, Target and Data*, 2011, p. 1.
- xvi The Wellcome Trust Submission of Evidence to the House of Commons Select Committee: *Attracting, training and retaining the best teachers*, October 2011, p.6. Wellcome Trust, *Subject knowledge and pedagogy in science teacher training*, 2011.
- xvii *Science and Mathematics Secondary Education for the 21st Century*, pp. 35-39, recommendation 6 and 7. Royal Society, *The UK's science and mathematics teaching workforce, recommendation 2.3*.
- xviii Alison Wolf, *Review of vocational education*, March 2011.
- xix *Respected: Technical qualifications selected for use in University Technical Colleges*, Matthew Harrison, 2011, p. 16
- xx *Science and Mathematics Secondary Education for the 21st Century*, p.66, recommendation 19; Royal Society, *Preparing for the transfer from school and college science and mathematics education to UK STEM higher education*, 2011, p. 54-55, recommendation 10. Levels of awareness of STEM careers amongst students were summarised in *STEM cohesion programme: final research report*, DfE ,2011, pp. 62 - 68.
- xxi Royal Society, *Preparing for transfer from school and college science and mathematical education to UK STEM higher education*, p. 54
- xxii *Science and Mathematics Education for the 21st Century*, pp.73-74.
- xxiii Royal Society, *Science and Mathematics Education*, 5-14, pp. 14-19.
- xxiv Committee of Public Accounts Fifteenth Report – *Educating the Next Generation of Scientists* pp. 7-8.
- xxv *Report to the Secretary of State, DIUS, on Universities' links with schools in STEM subjects*, led by Professors Julia Goodfellow and John Coyne, 2008.
- xxvi Royal Society *Increasing the size of the pool – a summary of the key issues from the Royal Society's 'state of the nation' report Preparing for transfer from school and college science and mathematical education to UK STEM higher education*, p. 5.
- xxvii *Science and Mathematics Secondary Education for the 21st Century*, pp. 70-75.