Royal Society: Vision for science and mathematics education 5-19

Response by the Wellcome Trust

22 March 2012

Key Points:

1. The 'Vision' exercise is an opportunity for the Royal Society to assert high level principles to underlie its position on science and mathematics education. The Wellcome Trust is committed to making inspiring, high-quality science education available to all young people. We are therefore pleased to respond to this call for evidence. We would be happy to expand upon evidence provided in this response and contribute further to the development of the Royal Society's vision.

2. Our main response focuses on some of the key areas requested in the consultation document, namely the need for high quality teaching, curriculum and assessment, and governance and accountability. In moving towards a vision for science and mathematics education, these aspects of the current system must be improved.

3. We also provide the following thoughts that you may wish to consider as you develop the overall vision.

    - At the highest levels, achievement in science and mathematics education are already excellent in the UK. The challenge is to close the very wide gap between the best and the average and below average, without losing the high level of excellence that currently exists.

    - The highest priority should be given to improving the scientific and mathematical literacy of the future citizen – while at the same time ensuring that the new generation of scientists and technologists are inspired and well prepared.

    - To achieve the principles above, it will be vital to ensure that teaching of science and mathematics is of the highest quality. Teaching in these subjects should be situated within rich real-life contexts, and ensure that students understand the methods of science as well as the facts and theories.

    - Practical work is essential to any science education setting, providing young people with hands on experience of how science works. In an increasingly technological world, virtual platforms for science learning are likely to become more commonplace. While these will have their place, those that mimic the "practical experience" of science must not detract from the importance of real life physical learning. This is particularly important if we are going to equip the scientists of tomorrow.

    - There are many cultures where vocational learning is more highly valued than it is in the UK, with little disparity between academic and vocational routes. The UK would only benefit from greater recognition of vocational routes to science learning. Vocational education will become more important as the age of compulsory education and training is extended to 18.

- Any future education system will require appropriate means of assessment and accountability. The current accountability framework has a distorting influence on how young people are taught in schools. Work is needed to create an accountability framework to measure the performance of the education system that is separate from, and is not solely driven by, pupil assessment. Similarly, an assessment system must be created that tests deep learning of science, and is relevant to how skills will be used in work and life.

4. Depending on the timeframe of the vision for the future, it will need to consider how the currently somewhat turbulent expansion of the diversity in education for both teachers and students will settle, as well as advances in educational technologies.

TEACHERS (AND THE WIDER WORKFORCE)

5. No education system can be better than the quality of its teachers. The quality of teaching has been shown to be a major determinant of young people's interest and achievement in science[1]. High quality and inspiring teaching from well-trained teachers is vital to ensure effective student engagement and therefore improve science and mathematics education going forward.

Recruitment and retention of high quality teachers

6. Recruiting and retaining the best science and mathematics teachers is vital. As mentioned in the call for evidence, there remains a shortage of science specialist teachers at primary and secondary level, particularly in the physical sciences. We support the move to increase the number of high quality teachers in the system through incentivising excellent science and mathematics graduates[2,3]. By steadily raising the bar, we are optimistic that the status of the profession will be enhanced, which, over time, will help to attract better qualified applicants.

7. One area of current concern regards bursaries to incentivise high quality graduates into primary teaching. A very low proportion of science and mathematics graduates enter primary training[4]. In maintained primary schools in England, only 3 per cent and 2 per cent of teachers are science and mathematics specialists respectively[5]. Those entering training for shortage subjects in secondary will receive £20,000. However, prospective primary teachers – even with qualifications in mathematics, chemistry and physics - will receive a maximum of £9,000. This disparity potentially acts as a disincentive for science and mathematics graduates to enter primary teaching. We believe it is important to bring the bursaries available to primary trainees up to the level for secondary trainees.

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[1] Wellcome Trust Monitor, Tracking Public Views on Medical Research, Butt *et al* (2009) http://www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_grants/documents/web_document/wtx058862.pdf

[2] Department for Education (2010). *The importance of teaching: the Schools White Paper* https://www.education.gov.uk/publications/eOrderingDownload/CM-7980.pdf

[3] Department for Education (2011). *Training our next generation of outstanding teachers* http://media.education.gov.uk/assets/files/pdf/t/training%20our%20next%20generation%20of%20outstanding%20teachers.pdf

[4] Royal Society (2007). *The UK's science and mathematics teaching workforce* http://royalsociety.org/uploadedFiles/Royal_Society_Content/education/policy/state-of-nation/SNR1_full_report.pdf

[5] The Royal Society (2010). "*State of the Nation – Science and Mathematics Education 5-14*". http://royalsociety.org/WorkArea/DownloadAsset.aspx?id=4294971776

8. Worrying data show that, of teachers receiving Qualified Teacher Status (QTS) in 1999, just fewer than 60 per cent of new recruits were still teachers after 5 years[6]. Providing interactions with Higher Education Institutions and employers, are important factors in improving retention. As is providing all teachers with access to high-quality continuing professional development[7], which is why Wellcome is strongly committed to the Science Learning Centres (see paragraphs 15 to 17).

Initial Teacher Training (ITT) and continuity with continuing professional development (CPD)

9. Those in the teaching profession must get the best possible training, in their early years as well as through the rest of their careers.

10. ITT is the first step to a successful career in teaching and therefore must be fit for purpose. It is a particular feature of science that teachers are often required to teach outside their first subject specialism: for example a biology specialist may well have to teach chemistry and physics up to GCSE level. An appropriate level of basic subject knowledge is therefore essential. The Trust recently commissioned a study from the University of Birmingham into the subject knowledge content of different ITT courses[8]. This study shows much variation across different institutions, particularly in the subject knowledge content of the school-based component of ITT. Steps must be taken to assure that trainees emerge with a minimum level of subject knowledge across all three sciences.

11. ITT and CPD should not be separate processes, but too often they are. Initial training is only the start of what should be a career-long process of professional development. Newly-qualified teachers (NQTs) still have much to learn, and although the best schools have excellent induction programmes at the beginning of the NQT year, the process is far from complete at the end of the year.

12. Teachers realise the need for CPD in the early stages of their career. However, steered by their schools' management, they are more likely to take up opportunities for generic CPD rather than science specific courses[9]. We would like to see a more proactive strategy for systematically developing the skills and knowledge of science teachers, especially in the early years of their careers, to build on knowledge gained in ITT and link with CPD.

Continuing Professional Development

13. Good subject specific CPD should be a regular part of good teaching practice and is vital for increasing the quality of teaching in schools. It is particularly important for science

[6] Royal Society (2007). *The UK's science and mathematics teaching workforce* http://royalsociety.org/uploadedFiles/Royal_Society_Content/education/policy/state-of-nation/SNR1_full_report.pdf

[7] Report of the Science and Learning Expert Group (2010). *Science and mathematics secondary education for the 21st century* http://interactive.bis.gov.uk/scienceandsociety/site/learning/files/2010/02/Science-and-Learning-Expert-Group-Report-Annexes-31.pdf

[8] Roger Lock, David Salt and Allan Soares, University of Birmingham (2011). *Acquisition of science subject knowledge and pedagogy Initial Teacher Training.* www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtvm053187.pdf

[9] Roger Lock, David Salt and Allan Soares, University of Birmingham (2011). *Acquisition of science subject knowledge and pedagogy Initial Teacher Training.* *www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtvm053187.pdf*

teachers: to keep them up-to-date with scientific developments; to equip them with skills to deal with changes to the curricula; and to learn innovative techniques to explain contemporary science in the classroom. The availability of opportunities for teachers to undertake CPD should be monitored by Ofsted to ensure that each school places this as a priority for improving teaching[10].

14. The National Science Learning Centre (NSLC) and network of regional Science Learning Centres, funded in partnership by the Wellcome Trust and DfE, were established as a resource providing high quality subject-specific CPD to science teachers and technicians across the UK. By July 2011, 98 per cent of schools had used the National network of Science Learning Centres including over 50 per cent working with the NSLC at least once.

15. In addition, DfE, industry[11] and the Wellcome Trust joined forces in Project ENTHUSE. This initiative aims to address a continuing problem for teachers and schools to find the time and money to cover teachers attending CPD courses. ENTHUSE provides funding for CPD courses, travel and teaching cover for teachers from across the country to upgrade their subject knowledge and teaching skills at the NSLC in York. Similarly, DfE funds the Impact Awards for teachers attending courses at their regional Science Learning Centre.

16. Evaluations of the Science Learning Centres and Project ENTHUSE showed their significant impact on the quality of science teaching and attainment in UK schools[12,13]. The National Audit Office recognise in its 2010 report[14] the impact that training courses supplied by the National Network of Science Learning Centres have had in improving teaching and increasing take-up of science and mathematics in schools. It is imperative that ongoing support for these initiatives is maintained.

Science expertise in primary schools

17. Young people's interest in science is often sparked in primary schools, yet a survey by the Wellcome Trust and the National Science Learning Centre (NSLC) suggests that many primary schools have experienced a decline in the status of science in recent years[15]. This follows the removal of science tests at age 11, and is linked to the long-term weakness of primary teachers' knowledge and confidence in science, as observed in our 2005 report '*Primary Horizons: starting out in science*'[16].

18. As mentioned above, there is a need to provide the appropriate incentives to recruit high quality science and mathematics graduates into primary teaching in the long term. However, a more immediate problem is the lack of scientific expertise currently available

[10] House of Commons Science and Technology Committee (2011), *Practical experiments in school science lessons and science field trips*
http://www.publications.parliament.uk/pa/cm201012/cmselect/cmsctech/1060/1060i.pdf
[11] AstraZeneca, AstraZeneca Science Teaching Trust, BAE Systems, BP, General Electric, GlaxoSmithKline, Rolls-Royce, Vodafone and Vodafone Group Foundation.
[12] https://www.sciencelearningcentres.org.uk/research-and-impact/networkimpactreport0910.pdf
[13] https://www.sciencelearningcentres.org.uk/research-and-impact/enthuseimpactreport.pdf
[14] National Audit Office (November 2010). *Educating the Next Generation of Scientists*
http://www.nao.org.uk//idoc.ashx?docId=95a6046d-8162-438c-b074-c9975db8a90e&version=-1
[15] Wellcome Trust (2011) *Primary Science Survey Report*.
http://www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtvm053596.pdf
[16] Wellcome Trust (2005). *Primary Horizons: starting out in science*.
http://www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtx026636.pdf

in primary schools. We believe that increasing the level of science expertise in primary schools is therefore a priority.

19. To address this, the Trust is developing a programme of CPD to train a primary science specialist in 50 schools. The programme will be aimed at teachers who are acting as primary science coordinator but do not have a background in science. Should the scheme prove a success after piloting and independent evaluation, we believe that it should be rolled out nationally with support from the Department for Education.

School laboratory technicians

20. Recent studies have shown that laboratory technicians provide invaluable support to teachers in schools and colleges in preparing and managing practical work and demonstrations[17]. Heavy workload has been cited as one of the main reasons for teachers leaving the profession[18] and the work of technicians also reduces the burden on the teacher. The challenges around the future supply of school technicians is of particular concern and must be addressed[19]. The profile of technicians, including pathways to become a technician and career prospects[20], must be raised along with good incentives to attract and retain them in schools, including CPD.

Careers advice

21. Careers advice and guidance in schools regarding all STEM (science, technology, engineering and mathematics) qualifications and their intended routes is critical and must be improved to ensure that students are aware of the different career opportunities and appropriate progression routes. The National Audit Office[21] listed careers information and guidance as one of five critical success factors in improving take-up and achievement in science.

22. The range of careers available to people with STEM qualifications is so large that it is difficult even for professional advisers to give fully informed advice. At present, young people depend on their families[22] (78 per cent), teachers (48 per cent) and careers advisers (20 per cent) for guidance. Following the removal of a ring-fenced budget for careers advice in schools, it is imperative that young people, parents and teachers are able to access good, clear information on career pathways and subject choices.

23. One way to help achieve this would be to expand and augment the existing Labour Force Survey and Annual Survey of Hours and Earnings to create a new, online and accessible resource on labour market information (LMI) to inform learners and their

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[17] Report of the Science and Learning Expert Group (2010). *Science and mathematics secondary education for the 21st century* http://interactive.bis.gov.uk/scienceandsociety/site/learning/files/2010/02/Science-and-Learning-Expert-Group-Report-Annexes-31.pdf

[18] Smithers and Robinson (2003). *Factors affecting teachers' decisions to leave the profession* https://www.education.gov.uk/publications/eOrderingDownload/RR430.pdf

[19] National Strategic Skills Audit for England, Skills for Jobs, Today and Tomorrow, UKCES (2010) http://www.ukces.org.uk/reports/skills-for-jobs-today-and-tomorrow-the-national-strategic-skills-audit-for-england-2010-volume-1-key-findings

[20] Such as *'A career structure for science technicians in schools and colleges'*. http://www.education.gov.uk/b00202532/school-support-staff/roles/technical/science-technician

[21] National Audit Office (November 2010). *Educating the Next Generation of Scientists* http://www.nao.org.uk//idoc.ashx?docId=95a6046d-8162-438c-b074-c9975db8a90e&version=-1

[22] Hutchinson, J., Stagg, P. and Bentley, K. (2009) *STEM Careers Awareness Timelines. Attitudes and Ambitions Towards Science, Technology, Engineering and Maths (STEM at Key Stage 3)*. http://www.derby.ac.uk/files/icegs_stem_careers_awareness_timelines.pdf

parents about the earnings and opportunities in different occupations, and the qualifications needed to enter them.

CURRICULUM AND ASSESSMENT

24. Our points in this section refer mainly to the National Curriculum, assessment mechanisms, and the need to increase the mathematics content of science qualifications.

National Curriculum

25. Over many years the existing National Curriculum has been subjected to multiple piecemeal changes that have contributed to it being over-prescriptive and inflexible. Although there is currently a review of the National Curriculum, we would like to see a commitment to an agreed long-term (at least 10 years) vision for the National Curriculum that policy makers, teachers and other stakeholders could work towards.

26. In July 2010 the Wellcome Trust convened a seminar to reflect on 21 years of the national curriculum for science. The report from the seminar provided five key messages which are designed to aid policy makers and curriculum reformers[23]. This is particularly pertinent with the current review of the National Curriculum, but the principles remain relevant for the future.

    i. The aims and purpose of the national curriculum for science must be clearly articulated and adhered to.

    ii. The body of core knowledge should be clearly defined but not over prescribed.

        - careful attention must be given to how subject content is presented so that the context of what is taught is not lost in place of facts alone. Each subject should display an appropriate balance between information (what we know), skills (how we do things) and concepts (what we understand).

    iii. Assessment should be designed as an integral part of national curriculum development.

        - National Curriculum should be intrinsically linked to assessment. Appropriate means of assessing young people's progress and achievement must be developed to follow, not drive, what is taught in schools.

    iv. New developments should be carefully piloted and rigorously evaluated before being refined and rolled-out nationally.

    v. The implementation of a new curriculum must be carefully planned to ensure that all parties involved understand how it should be applied.

        - When introducing new curricula, it is crucial to encourage and support teachers through guidance, teacher training and ongoing CPD. This will promote confidence and understanding of how best to apply the curriculum, and provide ongoing stability for the teaching profession.

[23] Wellcome Trust (2010) Summary report of the seminar "*Leading Debate: 21 Years of the National Curriculum for Science"*
http://www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtx063344.pdf

Assessment

27. Assessment should be intrinsically linked with the curriculum. Appropriate assessment should be designed to support learning, improve achievement and promote progression. The danger with any assessment system is that learning becomes directed towards achieving the best examination results rather than giving students a broad understanding of a subject - "the tail that wags the dog"[24].

28. We support assessment that enables a good balance between formative and summative outcomes. It will need to inform students, parents and teachers of young people's attainment and progress, as well as assist children to chart their own learning, build their confidence and offer a constructive critique on their progress[25]. It should not be used as an overall measure of system performance due to the distorting influence on learning outcomes (see paragraph 37).

Examination system and supporting materials

29. An appropriately run examination system in England is vital for qualifications across the breadth of education. The examination system must be fit for purpose and ensure that young people are taught deep knowledge of science and mathematics subjects rather than being "taught to the test". This is currently being investigated by the Education Select Committee and Ofqual, but any reforms will need close monitoring over the coming years to assess if improvements have been made.

30. There are significant problems arising from the current model of multiple awarding bodies for academic qualifications for 15-19 year olds. If we were establishing the examination system from scratch, a single awarding body would be most favourable and would be that envisaged in an ideal vision for the future. If the current model persists, it needs substantial improvements, specifically:

    - There needs to be greater consistency across awarding bodies in the process of awarding grades, and much more openness about how it works.
    - Awarding bodies must communicate better with each other, especially in sharing best practice and introducing innovations.
    - National subject committees should be established to oversee the standard of examinations of major subjects across <u>all</u> awarding bodies.
    - The changes to specifications every five years should be discontinued and awarding bodies given the ability to make incremental changes to examinations as and when needed, under the guidance of national subject committees.

31. In addition to this, we also believe more should be done to promote the value of STEM subjects to Higher Education Institutions and employers, to ensure that pupils are not

[24] Report of the Science and Learning Expert Group (2010). *Science and mathematics secondary education for the 21st century* http://interactive.bis.gov.uk/scienceandsociety/site/learning/files/2010/02/Science-and-Learning-Expert-Group-Report-Annexes-31.pdf

[25] Harlen and Qualter (2009) "*The Teaching of Science in Primary Schools*" (Paperback); Collins, Reiss and Stobart, 2008; Wellcome Trust, 2008.

put off taking them due to perceived difficultly in achieving higher grades as compared to other subjects. A recent report by the Russell Group provides a useful starting point[26].

32. Textbooks should be effective tools to aid deep and lasting learning. We are concerned that linking textbooks solely with awarding body examination specifications encourages "teaching to the test". Ofqual should use its Codes of Practice to stop awarding bodies endorsing textbooks wherever this carries a risk that the quality of the textbook and/or the associated examination will be compromised as a result of the association.

Increasing mathematics content and uptake

33. A specific area of concern is the low mathematical content of science specifications and examinations at GCSE and A level, highlighted by the report of the Science and Learning Expert Group[27]. Mathematical content should be strengthened within the science specifications and, most importantly, required in the actual examination questions. This is something that Ofqual can and should demand as a matter of urgency.

34. People need fluency, confidence and the ability to apply mathematics in study, in the workplace and in their personal lives. These qualities come from learning and using mathematics regularly over a sustained period. England (with Wales and Northern Ireland) has an exceptionally low rate of participation in post-16 mathematics (under 20 per cent[28]), and Michael Gove has set a new goal for the education system so that 'within a decade the vast majority of pupils are studying maths right through to the age of 18'[29].

35. With this level of concern, there is a singular opportunity to make progress towards the goal of continuing mathematics education for all young people until 18. Actions are needed on both the supply side (ensuring there are the right high-quality post-16 qualifications in mathematics to meet the needs of all people, whether or not they are university bound) and the demand side (making sure that universities and employers speak loudly and clearly of their preference for mathematical qualifications). The Advisory Committee on Mathematics Education (ACME) can and should be the lead body to take this work forward, but it needs strong support from all stakeholders and may need additional resources.

GOVERNANCE AND ACCOUNTABILITY

36. It is important not to confuse the role and purpose of national accountability with assessment information for parents, teachers and pupils to guide and measure a pupil's personal progress. It is clear that that current system of school accountability, for example league tables based on pupil achievement in examinations, have a distorting influence that drive learning outcomes based on test results rather than deep knowledge of a subject. Further work is needed to create a framework to measure system performance separately from pupil assessment.

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[26] The Russell Group (2011). *Informed choices* http://www.russellgroup.ac.uk/media/informed-choices/InformedChoices-latest.pdf

[27] Report of the Science and Learning Expert Group (2010). *Science and mathematics secondary education for the 21st century* http://interactive.bis.gov.uk/scienceandsociety/site/learning/files/2010/02/Science-and-Learning-Expert-Group-Report-Annexes-31.pdf

[28] Nuffield Foundation (2010). *Is the UK an outlier? An international comparison of upper secondary mathematics education* http://www.nuffieldfoundation.org/sites/default/files/files/Is%20the%20UK%20an%20Outlier_Nuffield%20Foundation_v_FINAL.pdf

[29] Michael Gove speaks to the Royal Society on maths and science, 29 June 2011

37. We believe that one element of performance improvement and accountability of schools should include robust local governance of schools[30]. As part of this, careful thought must go into the training and recruitment to governing bodies to ensure appropriate experience and full understanding of the role of governing body members. The Wellcome Trust is investigating a number of initiatives in this area, such as producing something equivalent to a Statement of Recommended Practice[31] applicable to governing bodies, and would be happy to share the findings and developments as they emerge.

38. Overall, we believe that effective assessment and accountability can only be realised if there is additional work to:

- strengthen formative assessment within schools to guide and develop pupils;
- identify a suitable range of indicators of school performance;
- strengthen accountability through effective school governance and appropriate patterns and criteria for school inspection.

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[30] Report of the Science and Learning Expert Group (2010) "Science and Mathematics Secondary Education for the 21st Century" http://interactive.bis.gov.uk/scienceandsociety/site/learning/files/2010/02/Science-and-Learning-Expert-Group-Report-Annexes-31.pdf

[31] As used by the charity commission http://www.charitycommission.gov.uk/Charity_requirements_guidance/Accounting_and_reporting/Preparing_charity_accounts/sorpfront.aspx