

SCORE CONFERENCE SUMMARY REPORT



SCIENCE IN THE NATIONAL CURRICULUM

SCORE held a one-day conference on *Science in the National Curriculum* in London on 21 March. The aim of the event was to bring people from the science and science education communities together to inform the SCORE response, and to help individuals formulate their responses, to the Government's recent 'call for evidence' on its review of the National Curriculum. Over 100 participants had the opportunity to hear talks, and take part in discussions, on three key themes: the nature of science; how children learn about science; and does 'one-size fit all' at Key Stage 4?

This report is an overview of the day. This document does not represent the views of SCORE.

Professor Graham Hutchings FRS chaired the conference.

ABOUT SCORE

SCORE is a partnership of organisations, which aims to improve science education in UK schools and colleges by supporting the development and implementation of effective education policy and projects. The partnership is currently chaired by Professor Graham Hutchings FRS and comprises the Association for Science Education, Institute of Physics, Royal Society, Royal Society of Chemistry and Society of Biology.

SCORE's priority areas over the next four years are: the curriculum qualifications and assessment; the schools and colleges workforce; and the wider learning experience.



KEYNOTE SPEAKERS



NATIONAL CURRICULUM: NOW AND FOR THE FUTURE

Diana Garnham

Chief Executive, Science Council

In setting the scene for the conference, Diana Garnham said that one of the main challenges for the National Curriculum for science would be to underpin both academic and technical routes to progression. Recent research commissioned by the Science Council and others suggests that by 2017, over 58% of all new jobs will require STEM (science, technology, engineering and mathematics) skills – specifically mathematical and analytical skills, and ICT skills that go beyond being able to use a computer.

The key messages coming from a range of employers are that they will need people who can apply their knowledge, and who can manage their own work and lead teams. In the future all scientific and technical jobs will depend more on ICT and for those students who will not progress on to Higher Education, the education system must equip them for STEM employment.

Another strong message coming from employers is that they want STEM employees to have an appreciation and experience of the multidisciplinary nature of science in the 21st century. A knowledge and understanding of the core disciplines, and how they relate to each other, must be achieved through the education system. Level 2 skills will not be sufficient to meet the demand in the future so the National Curriculum will need to be designed to encourage progression from Level 2 to 3 and from Level 3 to 4.



We need to reach a consensus on what science we think we should teach 5–16-year olds.

Stefano Pozzi



NATIONAL CURRICULUM REVIEW

Stefano Pozzi

Assistant Director, Research Unit, National Curriculum Review Division



Stefano Pozzi explained that the Government wants a National Curriculum, for 5–16-year olds, which focuses on a core of essential knowledge (facts, concepts, methods, techniques etc), underpinned by evidence and informed by international best practice. The slimmer National Curriculum will leave time for schools and teachers to focus on pedagogy and on the contextualisation and application of knowledge and concepts.

Pozzi highlighted some of the key issues for science in the current ‘call for evidence’.

- The essential knowledge for science in the National Curriculum, including the provision with respect to ‘scientific enquiry’, and what should be left to the wider science curriculum.
- The balance between theoretical and practical knowledge.
- Whether the Programme of Study (PoS) for science should identify separate requirements for biology, chemistry and physics.
- Whether a year-by-year approach, rather than key stages, would improve planning and learning.
- Whether attainment targets and level descriptors are useful.
- Whether the attainment range is accessible to all learners.

Revision of the PoS for science will take place from mid-April to mid-June, drawing on evidence from the subject communities, research literature, and from an analysis of the curricula and education systems of other nations, such as Singapore and Hong Kong. The PoS for science is expected to be out for general consultation early in 2012, with the final version in schools by the autumn of 2012, ready for first teaching in September 2013.

Some interesting findings are emerging from the international work, explained Pozzi. For example, while all three curricula include ‘scientific enquiry’, England’s coverage is more demanding than in either Singapore or Hong Kong. However, the level of challenge of the content in both Singapore and Hong Kong is more demanding at secondary level than it is in England. Pozzi acknowledged that the findings won’t necessarily give answers to the issues raised in the review but they should help to develop evidence-based principles and criteria for good curriculum design.



Students from a very early age, right the way through to university, are going to have to keep in-step with all three science disciplines.

Diana Garnham



Summary of issues raised by delegates

National Curriculum review

- The aims and purpose of the National Curriculum should be clear, including its relationship with subject criteria and qualifications.
- The National Curriculum will never serve learners while league tables remain a priority for schools.
- There needs to be careful consideration to the implementation phase of the National Curriculum review, including adequate support and training for teachers.
- The National Curriculum must not be focused on the needs of other nations.
- Children learn from well-informed, enthusiastic and highly motivated teachers. Teachers need CPD (continuous professional development) to maintain their enthusiasm and to keep their own subject knowledge up to date.
- The multidisciplinary nature of science needs to be considered as part of the National Curriculum review.
- Progression in science teaching and learning, from primary through to secondary, is essential. There should be a more holistic approach to curriculum development, rather than a focus on Key Stage 4.

National Curriculum and assessment

- The National Curriculum and assessment are intrinsically linked: all content in the National Curriculum must take account of how it will be assessed.
- Assessment in science from Key Stages 1 to 4 is flawed and needs to form part of the review process.
- Setting objectives and collecting evidence on children's learning has become too complicated and time-consuming, and comes at the expense of developing their learning and engagement in science.
- Assessment in science needs to be broader than recall and short-answer questions to assess higher-level analytical and reasoning skills.
- Assessment of practical work needs to be reconsidered.



WHAT IS THE NATURE OF SCIENCE?

An understanding of the nature of science is essential to be able to evaluate the strength of evidence supporting scientific claims.

Robin Millar



THE NATURE OF SCIENCE

Robin Millar

Professor of Science Education, University of York

The nature of science, including How Science Works and progression through these aspects of science, explained Robin Millar, should be considered in light of the overall aims of science education for 5–16-year olds. These in turn should be underpinned by the purpose of education. For Western democracies the latter is linked to economic productivity, social cohesion, and personal development and fulfilment. The aim of science education, when understood as an element of general education, is to teach children as much of the best available knowledge of the material world that is appropriate to their needs, interests and capabilities.

For Millar the nature of science comes down to an understanding of what science is, what's distinctive about it, and 'how it works'. It is about understanding the sorts of knowledge that science produces, which range from the well-established facts to rather tentative explanations that may or may not turn out to be true. The nature of science includes methods that are used to obtain knowledge and test it, and the interrelationships between science and society.

Understanding the nature of science, explained Millar, is important because to claim to know anything means being able to say why it is so – in philosophical terms, it is the difference between knowledge and belief. There are other reasons – it helps people make sense of science in the media, and for students an understanding of the nature of science may influence the way they learn.

Essential knowledge in the Programme of Study for science should embrace the nature of science and include: content knowledge – knowledge about the material world; procedural knowledge – how to do science; epistemic knowledge – the nature of knowledge that is produced by scientific reasoning; and knowledge about science in society. Although the four types of knowledge would not carry the same weighting in a science curriculum, Millar believes they are all important and have a place in the core curriculum.

More specifically, he said, all students, from primary through to secondary, should know that the fundamental aim of science is to explain natural phenomena, and not simply to amass, collect and catalogue information. They should know something about the logic of evaluating and testing explanations of causal explanations, ie inter-variable investigations, and explanations based on theoretical models. By the age of 16, students should also know that scientific knowledge is the product of a community and not of isolated individuals. They should know some stories about the history of science and about current issues in science so that science education is part of their general education.





This aspect of the curriculum was given greater emphasis at GCSE without a commitment to developing appropriate methods of assessment.

Andrew Hunt



TEACHING ABOUT SCIENCE IN THE NATIONAL CURRICULUM

Andrew Hunt

Independent consultant

Andrew Hunt pointed out that one of the main challenges for the Programme of Study for science in the National Curriculum is to switch young people onto science. This won't be achieved by a fact-laden curriculum that doesn't allow students to engage with the critical questions about natural phenomena such as: 'How do we know that?', 'What don't we know?' and 'How are we going to find out?'. If only textbook, consensual knowledge that is entirely agreed is taught, young people will not be prepared for their adult lives, where most of the interesting science will require them to engage with experts who don't necessarily know the answer, and who often disagree. All this comes under the strand now called How Science Works – ie the nature of science and the place of science in society. Hunt emphasised that this was not new to the curriculum, the term was introduced in 2006, but various aspects of How Science Works have been at the heart of the curriculum for the past 50 years.

In 2010 SCORE commissioned a project, led by Hunt, to investigate the ways in which How Science Works features in GCSE specifications and how it is assessed. The team was also asked to put together a bank of exemplar test items, mainly from the most recently accredited GCSE specifications, to give teachers and examiners a better idea of how this strand of the curriculum should be assessed. The key ideas that define How Science Works can be grouped into four categories: the methods of science; the nature of scientific knowledge; the institutions and social practice of science; and science in society. The research found that within these categories there was a total lack of consensus about what should be taught, and how it should be assessed across the specifications. The intended learning outcomes for How Science Works are poorly formulated so it is not clear to teachers what they should be teaching. And because the specifications are not clear, examiners set poor exam questions. In general there was a huge emphasis on low-level questions about science in society which has discredited How Science Works.

There is a need to work towards a better understanding of what should be taught and how it should be assessed under How Science Works, explained Hunt. Moreover, there is currently no model for progression for this strand of the curriculum. The approach is different at Key Stage 3, 4 and at A-level, and this needs to be addressed. Investigative knowledge is more than a set of skills and needs to be developed through the key stages.



Summary of issues raised by delegates

Nature of science

- The nature of science should be embedded into the subject disciplines rather than stand alone as a separate attainment target.
- The categories that are defined by How Science Works are an essential part of the science curriculum, but the term needs to go because it is not meaningful to teachers and students.
- The outcomes of the strand of curriculum defined by How Science Works need to be clearly defined so that they can be taught and assessed, and the outcomes must show progression through the key stages.
- Currently there is no model for How Science Works and therefore no joined up thinking/consistency across the key stages.
- The assessment of How Science Works must not focus on science in society issues; this is only one area of How Science Works and the current assessment is not a fair representation.
- Investigative knowledge should be a key part of the knowledge and understanding of science.

National Curriculum and practical work

- Practical work is fundamental to science education and should be part of the entitlement of the National Curriculum.
- Practical work is more than a set of skills and should be described in terms of procedural knowledge.
- Learning outcomes of practical work need to be made clear to students by teachers.
- In order to support practical work in the National Curriculum, there must be appropriate resourcing in all schools.





HOW DO CHILDREN LEARN ABOUT SCIENCE?

Facts about the material world need to be placed in a bigger picture, one that informs future understanding and the development of the curriculum.

Professor Wynne Harlen, OBE



LEARNING IN SCIENCE AS THE DEVELOPMENT OF BIG IDEAS

Professor Wynne Harlen, OBE

Independent consultant

Wynne Harlen OBE, drew on her own research into the use and development of 'big ideas' in the teaching and learning of primary and secondary science.

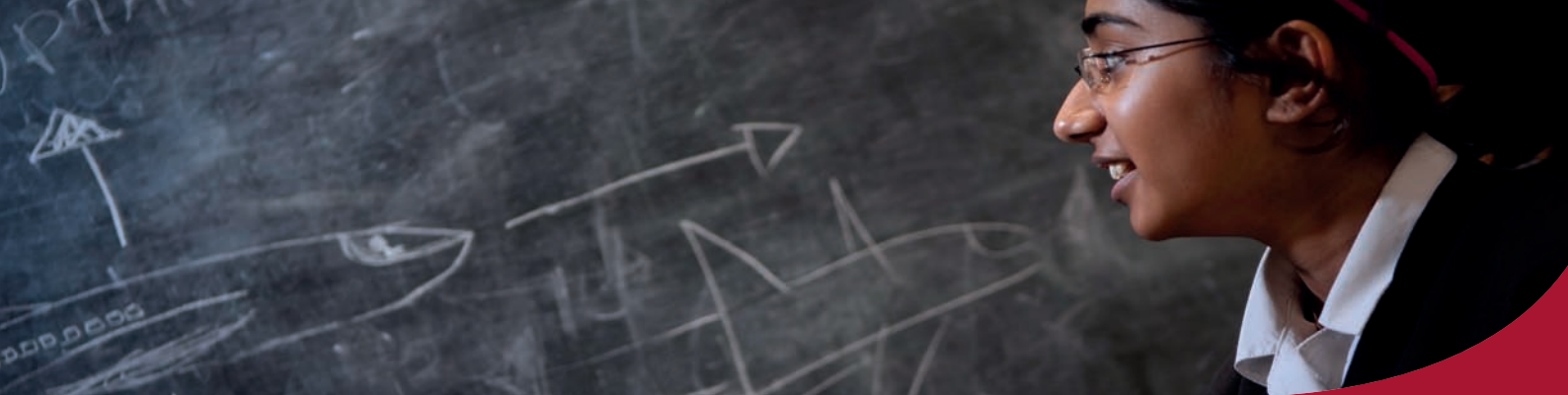
Learning science should be progressive – developing bigger ideas from smaller ones, she said. Students develop understanding through their own thinking but they need help in testing their ideas in a scientific way otherwise they may only confirm their pre-existing, non-scientific ideas. The role of the teacher is to enable students to test their understanding so their knowledge becomes more encompassing and more useful.

There are pragmatic reasons for focusing the science curriculum on big ideas. It is a way of selecting the most relevant from an enormous range of content. Teachers and students need to know where they are going and this is done best by giving them some idea of what is important to learn. There are also principled reasons – science education should develop curiosity about the natural world, enjoyment of scientific activity, and enjoyment of understanding of how natural phenomena can be explained. This is important for every person, not just future scientists or even those who will use science in their jobs, because people need to take part in decisions that affect their own well-being and that of society.

Big ideas should therefore facilitate understanding of current issues about health, the environment, the use of energy etc. They should include ideas about scientific activity, such as gathering and using evidence. Learning science without knowing how ideas are developed requires young people to accept things without questioning.

Progression in the curriculum is important, so these big ideas should be developed from the start of education. But how these ideas are expressed – whether in terms of what students should be taught or what they should have learned at various points – needs to be debated as part of this review.

A curriculum expressed in terms of big ideas to be understood, said Harlen, will endure for a longer time than one based on specifics. The content would need to be revised regularly as scientific knowledge expands, but the broad explanatory frameworks are likely to endure much longer.



Children need time to consolidate the message that they are getting from different angles to develop their understanding.

Professor Christine Howe



FOUR MESSAGES FROM PSYCHOLOGY

Christine Howe

Professor of Education, University of Cambridge

Christine Howe provided a psychological perspective on curriculum design and reform. She had four key messages, based on research into the acquisition of science knowledge.

Recognise and build on the recognition abilities that children bring to school.

Science education is concerned with explicit knowledge about the physical world, the kind of knowledge that is used in reasoning, eg when planning experiments, predicting outcomes etc. But underpinning this is a body of 'tacit knowledge', which allows children to differentiate between natural and non-natural actions. This is important because there are all sorts of things that children know at the tacit level before they go to school which are relevant to science and need to be recognised and built on, but not necessarily taught.

Recognise that topics need to be revisited and consolidated to support effective learning.

Children get different messages from the media, from their parents etc, and research evidence suggests that this leads to their science knowledge being a network of fragmented elements. This implies that topics need to be revisited using lots of different tasks rather than simply teaching a topic once and moving on to the next. Howe suggests moving away from a check-list approach to the curriculum, while preserving the key stage approach since this provides more opportunity for revisiting ideas than a year-on-year approach.

Recognise that developmental research has things to say about how topics should be sequenced.

A core curriculum based on big ideas (such as outlined by Wynne Harlen) may be a good starting point but the sequence in which topics are taught should be informed by research into how children learn. The relationship between knowledge and cultural practice can, for example, provide some insight into what, and how, science should be taught. These should not be downplayed in curriculum design.

Teach wider investigative skills rather than merely planning/doing/interpreting.

Epistemological perspectives – eg the ability to use data sets to draw conclusions – are challenging at all ages and need to be taught. Simply because children can differentiate beliefs from evidence doesn't mean that they can use that evidence to assess their beliefs. Research finds that evidence can support small changes in conceptual understanding but is unlikely to support great leaps forward: evidence will typically be discounted unless the target construct already seems plausible. This implies that progression in investigative skills needs to be considered as part of curriculum reform.



Summary of issues raised by delegates

- The National Curriculum should incorporate some of the same 'big ideas' across all key stages to encourage learning and progression.
- A curriculum that is set out on a year-by-year basis would allow for greater coherence within and across disciplines but it could favour a treadmill approach to teaching and discourage creative teaching which draws on links from other subjects.
- A curriculum which is set out on the basis of key stages would allow for ideas to be revisited, which is important for student learning.
- High quality research evidence should inform ideas about progression.
- Students need a range of different teaching and learning activities – practical work, discussion, independent and group learning, as well as teacher presentation.



Group work can be important in stimulating the process of change, simply because it brings a lot more ideas out in the open.

Professor Christine Howe



DOES ONE-SIZE FIT ALL?

The National Curriculum has been in place for over 20 years but we are just starting to see some diversity, which is a good thing and should be developed in a systematic way.

Professor Mary Ratcliffe



CHOICE AND ENTITLEMENT

Professor Mary Ratcliffe

Associate Director, Myscience

The structure of the National Curriculum for science, explained Mary Ratcliffe, needs to be thought of from the choices available to, and entitlement of, students as they approach Key Stage 4. Good practice in science education in schools and colleges at Key Stage 4 was recently identified in both an Ofsted report¹ and the Wolf report² as providing a range of science courses to match student needs and good advice to students about curriculum choices and progression routes. The Ofsted report also finds that ‘successful’ science education ensures that the science curriculum is engaging and requires students’ active participation within and beyond the classroom.

When it comes to ‘choice’, it’s the school or college that controls what’s available to the students. So the counter side of choice, ie entitlement, is very important. And the National Curriculum review implies that the curriculum should comprise a ‘core entitlement’ – what all young people, from 5 to 16, should know and understand about science. Identifying what should be in the core for the wide variety of qualifications and routes available at Key Stage 4 – for triple science, double science, BTEC etc – will be challenging.

A recent survey carried out by the National Science Learning Centre, to inform its response to the National Curriculum review, asked science teachers in England, among other things, what key ideas might be included as part of the core entitlement. Over 600 teachers responded, with about a third from the primary sector and about two thirds from the secondary sector. In an initial analysis of the responses, Ratcliffe found that there was overwhelming support, in principle, for the big ideas defined by Professor Wynne Harlen’s research. High priority areas for teachers were the ideas about science – explanations, theories, models and applications of science.

The survey also asked teachers whether the Programme of Study for science should identify separate requirements for biology, chemistry and physics at each of the key stages. At Key Stage 4 the majority of teachers said yes, reasoning that these subjects need to be taught by subject specialists, and the identity of each subject needs to be clear. However, the real world is a multidisciplinary environment so it will be important to be able to make links between the subjects.

1. Successful science – An Ofsted evaluation of science education in England 2007- 2010, published in January 2011, www.ofsted.gov.uk/publications/100034

2. Independent Review of Vocational Education carried out by Alison Wolf, published in March 2011, <http://www.education.gov.uk/publications/standard/publicationDetail/Page1/DFE-00031-2011>





There is an issue about when we go for commonality and when we start to go for diversity.

Professor Jim Donnelly



APPLIED SCIENCE AT KEY STAGE 4 AND BEYOND

Jim Donnelly

Emeritus Professor of Science Education, University of Leeds

Can one-size for the National Curriculum at Key Stage 4 work? The obvious answer, said Jim Donnelly, is no. Diversity at Key Stage 4 appears to be a preferable way forward. However, there is a whole set of issues which differentiate the current applied science qualifications from other Key Stage 4 science qualifications that need to be addressed, otherwise students on these courses could find themselves at a disadvantage. There is a balance to be struck between a common entitlement and stratification.

There is currently a range of Level 2 applied science qualifications on offer – with BTEC and OCR Nationals, in particular, growing in terms of uptake. At Level 3 there has also been a significant growth in applied science qualifications, though the numbers are not comparable with specialist A-levels. But as Donnelly explained, there are issues with these qualifications that are of concern. For example, while an applied curriculum might be thought of as emphasising ‘applications’ as a route into science, as a means of motivating students, and making the subject more relevant, they are distinctive for other reasons including:

- they have less science content than the other Key Stage 4 and Key Stage 5 science qualifications;
- there is some emphasis on the work of scientists, though scientists are probably not the people who would follow this route;
- there is a reduced emphasis on examinations, and more emphasis on portfolios;
- students following these courses tend to be lower attaining;
- they are not considered as preparation for either post-16 studies in the separate sciences or university entrance to the traditional academic science courses;
- they are not considered to meet the requirements of the English Baccalaureate, though they do meet the requirements for the ‘two science’ criterion within schools performance tables.

As part of the current review, the character and rationale of applied science in the curriculum needs to be discussed along with issues such as who these qualifications should be aimed at, and whether they should have distinctive progression routes. Importantly, the position of the applied science specifications within school performance measures needs to be reconsidered. Overall, attention needs to be given to the desirability of developing Key Stage 4 and 5 provision which is stratified by student attainment and progression routes.



Summary of issues raised by delegates

Relationship between Key Stage 4 and its related qualifications

- One-size does not fit all. There needs to be a range of qualifications at Key Stage 4 to reflect different abilities and interests, with the outcomes and progression routes of each clearly stated.
- Children learn in different ways and at different rates, and this must be acknowledged as part of the National Curriculum.
- There is a need for evidence on the benefits of double award science versus triple award science.
- A National Curriculum for science up to the age of 14 to allow for greater diversity from 16 should be considered.

Essential knowledge at Key Stage 4

- Core science should be an entitlement for all learners because it reflects the importance of STEM subjects in the economy.
- The three sciences should be clearly identified and have equal weighting, and links to other subjects such as maths and geography should be clear.
- The place of applied science in the core needs to be considered.
- There are areas defined by How Science Works that are important to all learners and should be in the core.
- The core should enable progression to academic and vocational options. A focus on scientific literacy in the core does not do this.
- If the Programme of Study for science is defined in terms of biology, chemistry and physics, there must still be recognition of the wider sciences, including Earth Science.
- Careers in science should feature as part of the core.

