ABOUT SCORE

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

SCORE’s priority areas over the next four years are: the curriculum; qualifications and assessment; the school and college workforce; and the wider learning experience.

ASSESSING THE SCIENCES
EXPLORING WAYS ASSESSMENT CAN PROMOTE AN AUTHENTIC EXPERIENCE OF THE SCIENCES

Around 150 people attended the SCORE annual conference at the Royal Society, in London, on 26 February 2013.

Now in its fourth year, the conference brought together people from the science and science education communities, as well as policy makers, to examine ways in which assessment can promote an authentic experience of the sciences.

The delegates took part in discussions of what is a timely subject in light of the current Government reforms at Key Stage 4 and A-level. They heard talks on the importance and challenges of assessment, and of a new model of assessment that is defined by what is learnt rather than by what is taught. Two workshops encouraged the delegates to put forward their ideas on how mathematics should be assessed by the sciences, and on the assessment of practical work.

This report is an overview of the day.

Professor Graham Hutchings FRS chaired the conference.

‘Our vision is a qualification system that supports high quality teaching and learning and enables students to demonstrate their knowledge and skills through well designed and appropriate assessment’.

Graham Hutchings FRS, SCORE Chair
Charles Tracy explained SCORE’s interest in assessment. ‘More than any other single factor, it is assessment that determines what is taught, when it is taught and how it is taught’, he said.

Whether summative or formative, all types of assessments in schools use some questions, the style and content of which are largely determined externally. Terminal exams inevitably influence formative assessments, such as end-of-topic tests, and this has led to a growing concern of an increase in ‘teaching to the test’. But if the tests are good, then both preparatory work and summative assessments will ensure that the quality of learning is also good.

The complexity of the assessment system, with so many interested parties and drivers, is a cause for concern to SCORE, he said. The purposes of assessment for students, schools, government, and awarding organisations are different and contradictory, and lead to tensions within the system. The result is that those which are ‘high stakes’, such as those used for performance measures for schools and the national system, seem to dominate.

Importantly, there are no drivers within the system to ensure that standards over time and between subjects are maintained, nor to encourage the development of high quality questions that could help to raise the quality of education. Instead there is the temptation for schools to focus on how the system rewards them and for the awarding organisations to compete on ‘accessibility’, to the detriment of learners.

To ensure a high quality education in the sciences for everyone, the assessment system, right down to the level of assessment items, has to be of high quality.

Issues raised by the delegates

- School governors have a role to play in holding schools to account and could therefore ensure that they prioritise aspects other than achieving the threshold of five A*-C grades, for example enrichment activities, practical work etc.
Katie Farrington explained that the motivation behind the Government’s current education reforms is England’s poor position in the international comparison tables for science and mathematics. At the heart of the Government priorities, she explained, are curriculum reforms that will encourage more pupils to study mathematics and science post-16, and the recruitment of the best graduates into teaching and retaining them through better training and continuing professional development (CPD).

The new National Curriculum programme of study (POS) for science will be in schools in September 2013, for first teaching in September 2014. The new science GCSEs will follow for first teaching from September 2015. The POS for science, she said, is deliberately more challenging, with an increased level of specification. Key elements of ‘working scientifically’ – i.e. new terminology for ‘scientific enquiry’ or ‘how science works’ – are set out for each key stage but will be ‘embedded’ through the subject content. There is also greater emphasis on the mathematical requirements for science at each key stage.

For the GCSEs in the three separate sciences and in combined science, there will be greater emphasis on problem solving and they will be linear qualifications (assessment will be at the end of the course); higher and lower tier papers have been scrapped; controlled assessment will be limited to practical science; and there will be a new grading system. On the advice of Ofqual, the Government will not be moving to a single awarding organisation for GCSEs.

The new A-levels are expected to be in schools in September 2014 for first teaching in September 2015. They, too, will be linear qualifications, the content of which will be informed by universities (the Russell Group is leading the reforms), expert organisations and learned societies, in consultation with teachers. AS levels are expected to stay but will be stand alone qualifications completed over one or two years.

Post-16 mathematics is a top priority for this Government – England has the lowest number of 18-year olds studying mathematics out of the OECD countries, which is neither good for an individual’s job prospects nor the economy, she said. The Government is currently working with ACME (Advisory Committee on Mathematics Education), among others, to develop new qualifications for the large numbers of students who get an A*–C in GCSE mathematics but who do not continue studying the subject. This strategy, she said, should bode well for science study and science careers.
Issues raised by the delegates

- Most of Europe sees the value of, and is moving towards, an enquiry-based curriculum for science, and this should be fed back to the Government in the current consultation.

- With the demise of QCDA, the process for developing the new GCSEs is in danger of being flawed because of the lack of subject-based expertise held by the awarding organisations and Ofqual, who now drive this process.

- Students starting A-levels in 2015 will have studied the old GCSEs, but those starting in 2017 will have studied the new GCSEs; it would make sense to delay the new A-levels until 2017.

- The introduction of computer science as an option for the English Baccalaureate may threaten the uptake of the other three sciences at GCSE. If this does happen, the Government may have to re-think this option.

- There will be no extra financial support to help schools introduce the new National Curriculum, instead this will be led by head teachers.

- Academies, which account for over half the secondary schools in England, do not have to follow the National Curriculum, so it will be important for these schools to be monitored by Ofsted to ensure that they deliver an effective and appropriate curriculum.

‘The [Government’s] intention is to move to a system where GCSEs are highly respected qualifications in which pupils, employers, parents, higher education institutions, further education institutions can have faith’.

Katie Farrington, Department for Education
Jo-Anne Baird began her talk by reflecting on the current assessment system. Over the years, there has been a centralisation of curriculum and assessment design, with too little input from practising teachers, with the result that there is now a policy–practice divide. So, while England is consumed by costly reform cycles, she worries they are not having an effect on the content of qualifications nor the learning that occurs in the classroom.

The timescales for reform are part of the problem. Political timescales are driven by the need to make an impact before the next election, which makes little sense in terms of assessment reform.

Her own research on the A-level assessment reforms, which began in 2005 and were completed in 2010, showed that most of the time available for reform was taken up developing policy. The examiners, who were also practising teachers, had just three months to change the content of the exams, so there was no time for innovation nor deep thinking about what was needed in science.

Looking back, she described how assessment had changed over the years as different theories emerged of how children learn. She cited Mary James’ ‘three generations of learning theory’ and how these influenced assessment: ‘behaviourist’ theory led to assessment of knowledge as defined by an authority; this was followed by ‘thinking matters’, which led to evaluating and problem-solving, extended tasks etc; and socio-cultural theory, which assumed that knowledge doesn’t exist independently of society, so assessment was linked to what people thought was important. ‘We actually changed how we assessed children because we had different ideas about how children learn’, she said. Importantly, this research showed that different kinds of assessment influenced learning. ‘The forms of tasks actually matter, they have a big backwash effect on how things are taught and how they are learned’, she said.

She also pointed out that with the demise of organisations like QCDA, which had dedicated subject specialists, came a loss of ‘institutional logic’ in education reforms. Ofqual, she said, has not been tasked to deal with the subject specifics of assessment; its expertise lies in regulatory matters. The understanding is that the Russell Group will tackle this but its remit is the broader curriculum and not the actual assessments, so this needs to be addressed. Ideally, she said, we need subject panels to look after this level of detail.
Issues raised by the delegates

- Policy should be informed by research evidence.
- One way of influencing policy is through the professional bodies because they do talk to politicians.
- The rapid timescales on which politicians change policy is a strong argument for subject specialists to be available to give ministers a long-term perspective.
- Group work assessment could be useful in science but needs more thought so that all members are assessed fairly.
- Younger teachers do not understand the process of curriculum development and assessment because it is no longer part of their professional training, which leads to a lack of engagement with the process.
- In order to define assessment there needs to be clarity on what students are expected to be able to do at the end of a course. This would benefit from more open debate as occurs in Norway, for example. The involvement of the Russell Group in the curriculum should go some way to address this.
- There is a strong argument for better and wider stakeholder engagement through national subject panels.

‘Like other high-performing countries, we need national subject panels to look at some of the detail of the assessments and take it forward’.

Jo-Anne Baird, University of Oxford
Robin Millar and Mary Whitehouse introduced the delegates to the York Science Project, which aims to embed assessment into routine classroom practice.

In general, Robin Millar explained, most people agree that the purposes of assessment are to: collect evidence of student learning (formative); measure attainment (summative); and provide evidence of the effectiveness of teachers and schools, and encourage them to improve (accountability). A more fundamental purpose that underpins all three, he said, is that assessment clarifies the intended learning outcomes of any lesson, course etc. ‘Until we’ve written down a question or task that would provide evidence that a student had attained some given learning outcome, we don’t really know what the outcome means and we can’t communicate it to anybody else’, he said.

The project is informed by the research of Paul Black, Dylan Williams and John Hattie among others, which finds that the biggest influences on improving learning are:

- formative evaluation;
- feedback from students to teachers;
- direct instruction – similar to that done in Asian Pacific Rim countries, which comes down to teachers having a clear idea of the learning intentions and the success criteria of performance before they plan a lesson.

In contrast, this research found that problem-based learning and enquiry-based learning had less influence on learning.

This research suggests that learning outcomes can be significantly improved by helping teachers to embed assessment into their routine practice so that it informs what they do next. ‘The project is about shifting people’s focus from what is taught to what is learnt, from objectives to outcomes, from the intended curriculum to the attained curriculum’, he said.

Mary Whitehouse outlined how the project team has developed banks of evidence of learning items for six topics at Key Stage 3 – a mixture of questions, short and long, and tasks of various structures and designs, some leading to practical activities, others leading to discussion activities, for example. These formed the basis of a pilot study, funded by the Salters’ Institute, which collected feedback from teachers.
There are two challenges now facing members of the project team. First, they will need to write questions and tasks for the strand of the new Programme of Study for science at Key Stage 3, which asks for an understanding of processes and methods of science. Secondly, they will need to help teachers see assessment items not as raw materials for test and homework but as the basis for activities that will provide evidence of the quality of understanding of individual students in everyday practice. CPD will be necessary, explained Millar, to wean teachers away from a rather narrow view of assessment to one that embeds assessment in the teaching and learning process.

Issues raised by the delegates

- The current reforms are focused on the curriculum with little time being spent on assessment, which is the wrong way around – the learning outcomes should be considered first.

- In any politically-driven reform, the timescale is almost inevitably going to be too short to do anything well, so the science community needs to take a longer-term view and not be driven by the short-term priorities of politicians to produce something that is substandard.

‘We have to think about what learning we value. Assessment is the tool that pins that down’.

Robin Millar, University of York
The aim of the workshop was to consider the Key Stage 4 mathematical requirements for science in terms of learning outcomes. The delegates, working in their subject groups, first identified the requirements relevant to their science and the context in which they are or could be taught. Then they discussed ways in which students could demonstrate they had understood the requirement.

Mathematical requirements were grouped under the following topics: arithmetic and computation; handling data; algebra; graphs; and geometry and trigonometry. These were all found to be necessary for study of the three sciences at GCSE, and the relevant contexts were identified. However, there was some variation between the sciences in the detail. Some requirements were more relevant to one science than another – for example, an understanding of probability and mean were more important to the biologists than chemists or physicists, but the reverse was true when it came to manipulating and solving algebraic equations. In general, in cases where there was this variation, the requirement was thought to be important for students to understand but it did not need to be formally assessed by the sciences. The ability to make estimates of the results of simple calculations also fell into this category.

There were also a few requirements that the delegates thought would be better covered by Key Stage 4 mathematics or were more appropriate for A-level study. The requirement to ‘use calculators to handle sin x, cos x and tan x when x is expressed in degrees’, could, for example, be left to Key Stage 4 mathematics. The ability to visualise and represent 2D and 3D forms, including two dimensional representations of 3D objects was, for example, thought to be more relevant to A-level physics than to GCSE physics.

The delegates put forward their ideas on how each of the requirements could be assessed in terms of learning outcomes, in other words how the students could show they had understood and mastered the specific mathematical skill. These ranged from the simple, straightforward calculations and presenting data using the appropriate number of significant figures, to more creative delivery – for example, the physics group suggested that students could produce a revision tool or do a presentation to show other students how to manipulate equations, and the biology group suggested that students could investigate the link between diabetes and obesity to show they appreciated the amount of data that needs to be collected for confidence in the results.

‘Maths is the great enabler. It is a key foundation for science study and careers. We hope that equipping many more students to study maths at the age of 18 will lead to a richer vein of students coming through into science study and into careers.’

Katie Farrington, Department for Education
The aim of this workshop was to consider different ways of assessing practical work at Key Stage 4, examples of which were identified by SCORE. The delegates, working in their subject groups, discussed the pros, cons and potential improvements of these methods, and were encouraged to suggest alternative methods of assessment.

The following eight exemplar methods were discussed.

1. Students write a report on an investigation using their own data, but their practical skills are not observed nor assessed.
2. Students write a report on an investigation using data provided.
3. Students do a written exam that asks questions about practical work.
4. Students do a practical examination and write up their apparatus, method, results and evaluation.
5. Students are given an oral exam in which they are asked questions about a project they have done.
6. A teacher, or external examiner, observes students doing practical work.
7. An examiner listens to an audio or video recording of the students doing some aspect of practical work.
8. An examiner views an ‘artefact’ produced by the student in the same way they would for an art or Design & Technology student.

The delegates agreed that practical work is integral to the sciences, for developing students’ knowledge and skills and bringing the sciences to life. As such they agreed it should be assessed, but no single method stood out as being the ideal way to assess practical competencies at this level. Importantly, the chemistry group said that none of the listed methods would improve the quality or quantity of practical work done in schools.

In general, methods were deemed useful if they involved the students doing some practical work; developed a variety of skills that would be useful in later employment; reflected what real scientists do; were easy to manage and scalable; encouraged higher level of understanding of science; and were externally assessed or moderated. Methods were thought to be flawed if they didn’t assess practical skills or assessed a limited number of experiments; were open to abuse; needed significant teacher input and resources; didn’t include students’ own work; and didn’t deliver a spread of marks.
Improvements to the various method were suggested – the written exam, for example, which met many of the delegates’ assessment criteria could be improved if what is defined by practical work is extended to include practical methodology and if students carried out a set of core procedures/skills before the exam.

The delegates agreed that a multiple approach that generated a range of evidence was needed and there was support for students producing a portfolio or ‘lab book’.

There were some additional approaches identified by the subject groups, including the following: a selection of various skills ‘tests’ monitored by teachers throughout the course; the use of e-assessment; and opportunities for students to record practical work during the course, which could then be used as reference material for a practical exam.

‘We’ve lost the idea that the assessment at the end is to provide information for students or indeed to help them with their particular needs during their adventure at school.’

Charles Tracy, Institute of Physics
In the finale to this year’s conference, Martin Rees entertained his audience with a tour of the solar system, describing some of the most recent discoveries in his subject along the way. But before this, he stressed the importance of SCORE’s mission in science education. This, he explained, is threefold – to ensure the UK has the right science and technology skills to be able to compete with the best in the world; to develop a scientifically literate public that is capable of engaging with the ever-increasing scientific and technology-dependent issues in their lives; and to encourage innovative thinking that underpins future ideas and advances.

Formal science education, he said, is still geared too much towards the training of specialists and there is an urgent need for a broader post-16 curriculum that also encourages more students to study some form of mathematics. Problem solving is at the heart of all human endeavour, he reasoned. There is also a need to have more subject specialist science teachers in primary and secondary schools, but he emphasised that academic qualifications are not necessarily the sign of a good teacher – the ability to encourage inquiring young minds to experiment and find out how and why things work for themselves is arguably more important.

His inspiring digression into his own subject followed. He went from the work of the heroic giants, Isaac Newton and Neil Armstrong, through the insights on the planets made possible by NASA’s spacecrafts Curiosity and the Cassini probe, to how Doppler measurements of stellar radiation make it possible to detect the presence of as yet undiscovered planets. All of this, he said could be passed on to A-level students and to the wider public. Key to this, he said, is communication that avoids the use of equations and specialist vocabulary, and importantly different use of familiar everyday words. He ended by highlighting the ever important role of education and science in dealing with some of the major challenges facing humanity, like climate change and the growing world population.

‘Science is part of human culture, more than that it is the one culture that is truly global’.

Martin Rees FRS