11 SCIENCE IN EDUCATION: IMPLICATIONS FOR FORMAL EDUCATION?

People's experience of science in schools is crucial in shaping attitudes to the subject. And their recent experience has not been great. School education has the need both to educate the next generation of scientists and to prepare much larger numbers of people for life in a technologically advanced society. These twin aims can come into conflict. Recent GCSE curriculum reform, says **Robin Millar**, has finally grasped the nettle, offering options that are more tailored to these different needs – and are more closely linked to students' everyday lives.

For most people, most of what they know and feel about science comes from their school science education. Science is a mandatory part of the curriculum between the ages of five and 16. Yet discussion of public engagement with science tends to focus on informal science learning – from newspapers, magazines and television, through science centres and Science Week events, to the arts. If we want to have a significant and lasting impact on public views of science, and public engagement with science and scientists, then thinking about – and seeking to influence – young people's experience of science in school is central.

Perceptions of school science

Science, along with literacy and numeracy, is seen by many influential groups as a critical element of the school curriculum. This gives it status, and perhaps resources. But it also leads to anxiety about outcomes, impact and uptake – which is not expressed to the same degree about other school subjects. There are competing social demands on school science, from politicians, from industry and commerce, and from the scientific community, in addition to its intrinsic educational value in extending individuals' knowledge and skills.

In the UK, as in many developed industrial countries, there are currently serious concerns about the numbers of students choosing the sciences, particularly the physical sciences, beyond the compulsory phase of education. Whether this constitutes a 'crisis' is more open to debate; similar concerns have been voiced almost continuously in the UK for the past 150 years, since before the sciences had become established as secondary school subjects. Nonetheless, there may be reasons to believe that recent changes have exacerbated the problems.

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Alongside this, also in many countries, there is consistent evidence of a decline in students' attitudes towards school science during the secondary school years – with more recent evidence in the UK suggesting that this may now be starting earlier, in primary school. The consistency of students' views in many countries is a striking finding of the ROSE (Relevance of Science Education) project.[1] Three studies that looked in more depth at students' views of school science in three different countries (Australia, Sweden, UK) identify three common features:

- dissatisfaction with the experience of science lessons as 'teacher-centred content transmission'
- a perception of curriculum content as unengaging and disconnected from students' lives and concerns
- the view that science is a 'difficult' subject (at which many do not feel 'good enough' to succeed).

As a result, while many acknowledge that science is important, they feel it is 'not for them'.

While this research points to changes that might make school science more attractive to students, some aspects of the problem lie beyond the school and the curriculum, in general perceptions of science as an institution, and as a career, in society at large. These are less easy to change. A further challenge is that different aspects of the problem point to different – perhaps incompatible – responses.

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A central tension

The central challenge in designing a school science curriculum is in resolving the tension between its two main purposes. One is to help all students attain functional 'scientific literacy'. The other is to provide the first stages of a training in professional science, for some students. For the past half century (if not longer), the 'training in science' emphasis has been ascendant. The primary importance of 'sound foundations' for more advanced study is implicit in the

THOSE WHO CAN, INSPIRE

The UK's new network of Science Learning Centres provides science teachers with unrivalled professional development opportunities.

The national network of Science Learning Centres is an ambitious £51m joint initiative from the Department for Education and Skills (DfES) and the Wellcome Trust. Comprising one York-based National Centre (supported by £25m from the Trust), serving the UK, plus nine regional Centres in England (supported by £26m from the DfES), they offer professional development opportunities for teachers and technicians.

The initiative is the highest-profile example of the Wellcome Trust's extensive →

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Funding
£51 million joint funding from the Wellcome Trust and the Department for Education and Skills (2003)

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Left: Hair raising: practical science is highly engaging for school students.

structure, and the choice of content. Yet only a minority of those following a science course at any given level actually choose to go on to the next level. The failure to design courses to meet the needs of the majority of those taking them was highlighted by the Higginson Committee (1988) on the future of A levels, which saw it as: "The most fundamental error in the traditional GCE/A level system".[2]

The key to greater student engagement is making stronger and clearer links between the science that young people hear about outside school and the science they learn in school.

For while these two aims are widely recognised, and reflected in general in curriculum policy documents, the school science curriculum has invariably been designed on the assumption that a single form of science education can achieve both. Courses specifically designed for each purpose would, however, differ significantly in content, in depth of treatment and in emphasis. The characteristic quality of scientific knowledge – despite the fact that science educators often choose to stress that it is provisional – is that some of it, including almost all that is taught at school level, is consensually agreed, and to all practical purposes beyond dispute. So teaching science is constrained. The aim is not simply to help students develop their understanding of the natural world, but to help them towards *one particular understanding* of it. Learning science is an induction into a particular view of the world. As a consequence, as David Layton once put it, "at the school level...the acquisition of scientific knowledge is inescapably tinged with dogmatism".[3]

Thomas Kuhn famously argued that science is taught and learned through 'paradigms': "accepted examples of actual scientific practice – examples which include law, theory, application, and instrumentation together".[4] These shape and define a field of enquiry. Learning science for professional level practice requires extensive practice in using these paradigms, to the point where they become second nature. In Harry Collins's words, "it is romantic nonsense to imagine that potential science specialists can learn all the science they need without a lot of routine learning and practice along with indoctrination into traditional ways of thinking".[5]

These, however, are the very features of science education that many students find off-putting – as the following comments, reported by Osborne and Collins from their study of students' views of the school science curriculum, indicate:

> [In science], there's one answer and you've got to learn it...You just have to accept the facts, don't you?...It's just not as creative as English.
>
> In art and drama you can choose, like whether you're going to do it this way or that way, and how you're going to go about it, whereas in science there's just one way.[6]

To address such views seriously, while still offering something that is recognisably *science* education, is a major challenge. If, in addition, it is not apparent to many students how scientific knowledge is useful to them for any practical purpose they can imagine, we should not be surprised that so many study it rather half-heartedly while it is compulsory, and give it up as soon as it is not.

Where do we go from here?

The educational challenge posed by the nature of science and scientific knowledge cannot be denied – but can perhaps be reduced. Successive revisions of the science national curriculum have tried – by giving greater emphasis to the methods and procedures of scientific enquiry, the nature of scientific knowledge, and the forms of reasoning from evidence that are characteristic of science.

The two distinct purposes of the school science curriculum – scientific literacy for all and the first steps in a training in science for some – have for the first time been more explicitly recognised in the 2006 revision of the Key Stage 4 national curriculum. Rather than a single science programme, designed to take 20 per cent of the students' time (a double GCSE), the curriculum is divided into two equal components: core science and additional science. The core course focuses on scientific literacy – the scientific knowledge and understanding of science itself that we would wish everyone to have; additional science augments this by introducing some of the more abstract concepts that provide a foundation for studying science at AS level and beyond. An alternative additional course (applied science) adds further flexibility.

The model seems to offer a way of enhancing the scientific literacy of all students while also catering for the needs of future specialists.

This model has been piloted since 2003 by the Twenty First Century Science project – and a revised version of the course and teaching materials developed for the pilot are one (of the four) GCSE science specifications from which all maintained schools in England can choose from September 2006. The advantage of the core plus additional model is that allows the two purposes of the science curriculum to be considered separately – and courses to be designed that are 'fit for purpose'.

This pilot runs to July 2006, so any evaluation of its impact is necessarily provisional (three external evaluation studies are in progress and will report in autumn 2006). The responses of pilot schools have been strongly positive,

portfolio of work in science education. Few would argue that science education is fundamental to the public's relationship with science, and to modern society more generally. It has the challenging 'dual mandate': to begin training the next generation of scientists but also to provide a science education that enables the much larger number of people who will not be scientific specialists to thrive in a technologically advanced society.

Paradoxically, while science burgeons in everyday life, concerns continue to grow that young students within schools are losing interest in the subject – not least because what they learn in lessons often bears no relation to the science they experience all around them.

Moreover, modern science presents some unique challenges. The pace of change has never been faster; yesterday's science may well have been superseded by the time it filters into the classroom. New technologies offer a range of new opportunities to enhance the teaching experience. And traditional science teaching, based predominantly on the transfer of facts, now has to incorporate debate and discussion of scientifically or ethically controversial issues.

The Wellcome Trust has adopted a multifaceted approach to these fundamental issues. One strand of work has focused on curriculum development. The Trust has encouraged the consideration of scientific issues in the citizenship curriculum, and has also financially supported and advised on new curricula – such as the new Twenty First Century Science GCSE, which aims to provide a more relevant general education focusing on the nature of science and its social and personal impact, as well as the core scientific 'basics'. The Trust has also funded the development of an AS level in the History, Philosophy and Ethics of Science.

While curricula are crucial, even more so are the professionals that deliver them. The new Science Learning Centres represent a bold initiative to reinvigorate science teaching from the ground up, creating a new generation of highly trained, motivated and inspirational educators.

The Centres aim to deliver the highest-quality professional training for teachers, technicians and support staff working with children from primary to post-16 levels. Everyone attending a course (lasting from one to several days) at any of the Centres has access to one-on-one mentoring, modern facilities, regularly updated resources and support, bringing together research, industry and educational expertise. This training is further reinforced with continuing support in the form of classroom exercises and online materials. Ultimately, the hope is to reconnect teachers with their subject – something that Wellcome Trust-funded research has shown is highly prized by science teachers.[1]

Other specially commissioned research has focused on key questions in modern science education. The influential *Valuable Lessons* report[2] highlighted the difficulties science teachers encountered trying to teach controversial issues in the classroom and suggested possible ways in which they could be tackled, while *Primary*

in particular teachers' views on their students' engagement and interest. Teacher feedback suggests that the key to greater student engagement is making stronger and clearer links between the science that young people hear about outside school and the science they learn in school. Students respond to the message that that the science-related issues they hear about outside school are part of the school curriculum, not something that cannot be properly explored and discussed because of the pressure to 'cover the material in the syllabus'. In the hands of teachers who are persuaded of its merits, the model seems to offer a way of enhancing the scientific literacy of all students while also catering for the needs of future specialists.

Post-compulsory schooling

So much for the compulsory phase of science in schools. What about post-16 science education? The striking characteristic of A-level study in England is the freedom of choice of subjects and subject combinations, and the requirement to study a few subjects in some depth. Studies of patterns of A-level uptake over the past decade have shown a steady drop in numbers taking physics and chemistry, as a proportion of the age cohort and (more strongly) as a proportion of all A levels taken. More detailed analyses have also shown that more students take a mixed combination of A levels, rather than a group of 'science' or 'arts' subjects – with consequent effects on their available degree and career choices.

We cannot expect to increase participation in science significantly by changing students' views and opinions; rather we need to change the kinds of course we offer them.

Since the introduction in the late 1990s of AS-level qualifications, two new science specifications have been introduced with the aim of attracting students who might otherwise have stopped the formal study of science at GCSE. AS Science for Public Understanding was first offered in 1998. It is designed to consolidate students' understanding of science from GCSE level, and introduce them to some ideas that are useful in analysing and evaluating scientific information and claims. Numbers taking the course have risen steadily, from around 300 in 1998 to over 2000 in 2006. An external evaluation of the course saw it as "distinctive and different from the standard courses that form the core of mainstream, secondary school science education, both in this country and internationally", and found that "the overwhelming majority of students said that the course is both enjoyable and interesting".[7] They also reported similarly positive teachers' views.

The more recently introduced AS Perspectives on Science, a course emphasising the history and philosophy of science, similarly aims to attract students who might otherwise opt out of science beyond GCSE. It is too early to assess its impact. These two AS-level courses, however, reflect a common concern to find ways of making the study of science more attractive to students with a wider range of interests – and to show how science can be used to enhance understandings and skills that are of more general value, not only to those with a specific vocational reason for studying science. Both, in different ways, reflect the view that we cannot expect to increase participation in science significantly by changing students' views and opinions; rather we need to change the kinds of course we offer them. Both also offer opportunities – which are already beginning to be recognised and explored – for closer links and alliances between formal and informal science education, which can enable schools to benefit from the creative energy that is evident in many science engagement efforts, and those involved in informal science to hear more clearly the student voice on science and its impact on their lives.

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→ *Horizons*[3] took a look at the current state of science teaching in primary schools.

To encourage changes in practice, the Trust has also supported the development of creative approaches to science education, for example through the Creative Science initiative, which supported work on new approaches to science education that could be taken up by Science Learning Centres. Funded projects such as Citizen Science (see pages 45–48) continue this tradition.

Formal education arguably has the greatest long-term impact on individuals' relationships with science. It is therefore one of the most crucial areas on which to focus attention.

References

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2 **Valuable Lessons: Engaging with the social content of science in schools. Wellcome Trust; 2001.**

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Right: Science education shapes the way students will approach science throughout adulthood.