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FOREWORD

Taking scientific literacy seriously as a curriculum aim

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Introduction

In many countries, there is concern about the engagement of young people with science. Fewer are choosing to study science, particularly the physical sciences, in upper secondary school and at university level (for data on the UK situation, see Roberts (2002); for a European perspective, see European Commission (2004)). Across the years of secondary schooling when science is a compulsory subject, research studies from a range of countries show a decline in students' attitudes towards school science (Bennett, 2003). Many say that they find science difficult, dull and not relevant to their needs or interests. In the ROSE (Relevance of Science Education) Project survey, a majority of students in developed industrial countries indicated that they like science less than other school subjects, and relatively few aspire to careers in science (Sjøberg & Schreiner, 2005). Many students agree that science is important, but feel it is 'not for them' (Jenkins & Nelson, 2006). The ROSE data show a strong negative correlation between a country's level of development (using the United National Human Development Index) and the average ratings given by students from that country to positive statements about school science and about future careers in science. Sjøberg and Schreiner suggest that this indicates a mismatch between the image of science presented in school science courses and young people's sense of identity in the modern world. Whether or not we accept this interpretation, it seems clear from the evidence of many studies and reports in many countries that we need a fundamental reappraisal of the way we present science as a subject within the school curriculum.

Rethinking the educational role of science

The challenge facing science educators and those who make and influence science education policy at local, regional and national levels is nothing less than to re-think the educational role of science as a subject in the curriculum of all young people – to 're-imagine science education', as the title of one recent report puts it (Tytler, 2007). To justify teaching science to all young people, we need to go beyond rather bland statements about science being all around us and a major material influence on all our lives – and ask what, as a result, ordinary people need to know about science, both as a body of established knowledge and as an approach to enquiry, that will be functionally useful in their present and future lives, and will seem valuable and interesting to them as new insights about their situation as human beings.

Many of the current problems of science education have their origins in history. Half a century ago, in most developed countries, introductory science courses of the kind that can lead on to more advanced study of the natural sciences were offered at secondary school level only to the most academically able 20-25% of the age cohort. Gradually, in many countries, we have sought to broaden access to science, sometimes through moves towards more comprehensive forms of school organisation, sometimes by modifications to the content and depth of treatment of topics in the science courses. This has not, however, led to significant change in the kind of science courses we offer. Most school science curricula are still organised around the same major topics as the curricula of the mid-20th century or earlier. The dominant influence on curriculum content is the perceived structure of the scientific disciplines. Most science curricula are watered-down versions of curricula originally designed to prepare a relatively small section of the age group to progress towards more advanced study of science and perhaps to careers in science, or requiring a good knowledge of science.

The problem with this, which is too frequently overlooked or treated less seriously than it should be, lies in the nature of a ‘training in science’ – the kind of science course that is effective for developing the knowledge and skills that future scientists require. Kuhn (1962) argued that science is taught and learned through ‘paradigms’: ‘accepted examples of actual scientific practice – examples which include law, theory, application, and instrumentation together’ (p. 10). These shape and define a field of enquiry. Learning science for professional-level practice requires that students become immersed in these paradigms, to the point where they become second nature. The aim is not to help students develop their own personal understanding of the natural world, but to help them make *one particular understanding* of it their own. Learning science is an induction into a particular view of the world. A consequence, in the words of the leading sociologist of science, Harry Collins (2000), is that ‘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’ (p. 171).

These, however, are the very features of science education that many students find off-putting. Osborne and Collins (2000), for example, report the following comments from a study, using interviews and focus group discussions, of students' views of school science:

> P1: With science it's solid information and you've got to take it down.
> P2: … so when they teach you science you know that this is it, okay? There is nothing, you can't prove it wrong.
> P3: I mean you just have to accept the facts don't you? (p. 25)

> In English they mark you on … expressing your own knowledge, not only reading a story and answering questions. .. But in science it's more strict, 'cause you have to learn and just write it down. Everything's like, ordered, you learn about photosynthesis and write about photosynthesis, whereas in English if you want to write about a flower you can write a poem or something, like that, something creative. It's just not as creative as English. (pp. 28-9)

To address such views seriously involves asking questions about the purpose of school science, and hence about its content and emphasis. And it involves recognising that the school science curriculum has different purposes for different groups of learners, and finding ways to accommodate these. For all students (since future scientists are also citizens, and will become 'expert' in only a narrow domain of science), we need to develop courses that foster 'scientific literacy'.

Scientific literacy as a curriculum aim

Much of the recent discussion of the school science curriculum has centred around the idea of 'scientific literacy' as a curriculum aim. Although, as Roberts (2007) points out, there is no clear consensus among science educators about the meaning of the term 'scientific literacy', it is generally taken to signal a shift of emphasis, away from science courses designed to teach the kind of understanding of science that only future scientists really need, towards those that seek to develop the kind of understanding of science that all citizens require.

One reason why this shift of emphasis matters is simply a matter of numbers:

> "A central fact about science is that it is actually done by a very small fraction of the population. The total of all scientists and engineers with graduate level

> qualifications is only a few percent of the whole population of an industrialised country. Thus the primary goal of a general science education cannot be to train this minority who will actually do science." (Ogborn, 2004: 69)

Very few of us will ever be *producers* of new scientific knowledge. But we are all *consumers* of scientific knowledge and information – as we read or hear about science-based knowledge claims or use artefacts and processes that are based on scientific knowledge. The aim of basic science education should therefore be to help young people become more astute and better informed consumers of scientific information, in the forms in which they encounter it in everyday life. And to try to give them a sense of the pleasure that can come from understanding, at a basic level, some of the powerful ideas that science has produced to help us explain events in the natural world. Yet in many countries, the school science programme, and the choices of curriculum content and depth of treatment that are implicit in it, are based largely on the needs of the small minority who may go on to become professional scientists or to work in a job that requires an understanding of more advanced science.

The needs of that minority are, of course, important, both at the level of the individual and of society. We need a steady supply of people choosing to follow science-based careers. In many countries there is strong support for this purpose of science education, from government ministers and from the often powerful and influential scientists' lobby. Trying to achieve both these aims, however, introduces a fundamental tension into the design and planning of the school science curriculum. It is aiming to do two jobs: to foster the scientific literacy of all students and to provide a sound foundation for more advanced study of science for some students. The problem is that these call for rather different approaches: different choices of content and different emphases in teaching. If we provide a single science course to achieve both purposes, it is likely to achieve neither well. Addressing the perceived 'crisis' in science education today requires first and foremost that we recognise and address this tension.

Responding to this challenge

Rather than discuss these issues in the abstract, I want, in the remainder of this paper, to base the discussion around a curriculum development project in England that has been trying to address this challenge.

In 2000, the official curriculum regulator in England, the Qualifications and Curriculum Authority (QCA), invited tenders to develop a more flexible curriculum model for science for 15-16 year olds, and to consult widely on ways of making the science programme better suited to the needs of a wider range of students. The work was awarded to the University of York Science Education Group, who reported to QCA in February 2001 (UYSEG, 2001). On the basis of this report, QCA commissioned further work to develop the preferred model in more detail (completed in March 2002), and then decided to conduct a national pilot trial from September 2003.

The model proposed drew on ideas sketched out in the *Beyond 2000* report (Millar and Osborne, 1998), which in turn had been influenced by an earlier paper by Millar (1996). As a fundamental principle, *Beyond 2000* argued that “The science curriculum from 5 to 16 should be seen primarily as a course to enhance general ‘scientific literacy’” (p. 9) – but noted the need to achieve this whilst also catering for the needs of students who may choose to take further, more advanced science courses.

For students up to the age of 16, the science programme on offer in England in 2002 was based on the national curriculum (QCA, 1999). This set out a programme of study and attainment targets for science, on the assumption that students would study science for 10% of their time in primary school (5-11), 15% in lower secondary (12-14), and 20% in the final two years of compulsory schooling (15-16). The course was designed to be ‘broad and balanced’, meaning that it contained roughly equal amounts of three main sciences, plus smaller amounts of Earth science and astronomy, and included scientific enquiry processes as well as science knowledge content. The science courses taken by most students aged 15-16 (over 80% of the cohort) were called Double Award General Certificate of Secondary Education (GCSE) Science, as they were equivalent to two normal GCSE subjects.

The new curriculum model for the pilot trial divided the 20% of curriculum time given to Double Award GCSE Science into two equal components (Figure 1). One half would be a core Science course, equal in size to a normal GCSE in most subjects, taking 10% of students’ class time. This would have a ‘scientific literacy’ emphasis. Alongside this, two optional courses would be provided: Additional Science with a ‘pure science’ flavour, and Additional Applied Science. Students who thought they might wish to pursue science beyond age 16 would take one of these. The suite of courses based on this model became known as *Twenty First Century Science.*

Figure 1. The *Twenty First Century Science* curriculum model

GCSE Science 10% curriculum time Emphasis on scientific literacy (science for citizenship)	GCSE Additional Science 10% curriculum time or GCSE Additional Applied Science 10% curriculum time
ALL students do this	*SOME students also do one of these*

Separating the two aims of the science curriculum in this way allowed each of the component courses – the core course and the two additional courses – to be designed for its specific purpose.

It is, of course, one thing to say that a course will have a ‘scientific literacy’ emphasis and will try to develop the kind of understanding of science that all young people, future scientists and non-scientists alike, need as citizens of a modern, technological democracy. It is quite another to design and construct such a course. The great advantage of the curriculum model outlined above is that the separation of the two purposes of the science curriculum makes it possible to focus entirely on ‘scientific literacy’ as the aim when developing the GCSE Science course and teaching materials, without having to make the compromises that would be necessary if it were a hybrid course with multiple aims. But this still leaves open the question of how to design a course to foster scientific literacy, and how it might differ from the familiar and more ‘traditional’ form of science course for this school level. The next section of this paper will discuss how these issues were tackled in the *Twenty First Century Science* project, and outline the design of the core Science course that was developed.

Designing a science course to foster ‘scientific literacy’

I have already alluded to the lack of an agreed definition of ‘scientific literacy’. Many science educators, however, see ‘scientific literacy’ in terms similar to those of the authors of the US National Science Education Standards, who characterised a scientifically literate person as one who can:

- read with understanding articles about science in the popular press
- engage in social conversation about the validity of the conclusions in such articles
- identify scientific issues underlying national and local decisions and express opinions that are scientifically and technologically informed
- evaluate the quality of scientific information on the basis of its source and the methods used to generate it
- pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately

(based on National Research Council, 1996, p. 22)

If this is what we are aiming for, what knowledge and capabilities do students therefore need? Essentially we want to provide students with a 'toolkit' of ideas and skills that are useful for accessing, interpreting and responding to science, as we all encounter it in everyday life. But what science do we meet in everyday life? One way to start to answer this is to survey a sample of newspaper articles, television news reports and public information leaflets (of the sort that you can pick up on a visit to the doctor or dentist). The science topics that appear most frequently in the news are health and environment – followed by space, Earth science (volcanoes and earthquakes) and palaeontology (fossils) (see, for example, Entwistle and Hancock-Beaulieu, 1992; Pellechia, 1997). Many health and environment articles report a claim that a factor (such as a new drug, or a specific component of your diet or environment) increases or decreases the chance (or risk) of a certain outcome. Often such claims are uncertain or contested by other scientists, or by lobby groups or individual non-scientists. Some articles report or discuss applications of scientific knowledge (for example in new medical treatments, or methods of food production) that raise social, economic or ethical issues. Articles on space and Earth science topics, or about fossil finds, often involve theories and explanations of the origin and evolution of the universe or of *homo sapiens*. Again the application of these to the case in hand is often somewhat speculative and may be contested. What knowledge and skills enable people to deal more confidently and effectively with such information, and reach more informed judgments about it?

In *Twenty First Century Science,* our answer is that you need some *scientific knowledge* (that is, knowledge about the natural world) and also some *knowledge about science* *itself* – about its characteristics as a form of enquiry, about the nature and status of the knowledge it produces and the evidence that supports this, and about the ways in which science, technology and society interact and influence one another. The former we term *Science Explanations*, and the latter *Ideas about Science*.

Table 1 lists the *Science Explanations* included in the core Science course. More detail can be found in the course specification (OCR, 2008). The primary selection criterion was that an explanation should be included only if an understanding of it might make a difference to a decision or choice that a citizen could have to make, or to the viewpoint he or she might hold on an issue or decision at local or national level, or if it offered a culturally-significant view on the human condition (on our ideas about 'who we are' and 'where we are'). In other words, we used what Fensham (2003) has called 'different drivers' of curriculum choice decisions from those normally used. Many of the *Science Explanations* in Table 1 are well-established elements of the current school curriculum: the atomic/molecular model of chemical reactions, the idea of radiation, the gene theory of inheritance, the heliocentric model of the solar system, and so on. For these, key questions to ask are: what kind of knowledge, and what depth of knowledge, do people require? *Twenty First Century Science* takes the view that citizens need a broad, qualitative grasp of the major science explanations, which would allow them to relate the explanation in their own words. The detail which is often taught, and which many students find off-putting, is rarely needed.

Table 1. Science Explanations in *Twenty First Century Science*

SE1	Chemicals (the idea of a 'substance')
SE2	Chemical change (the atomic/molecular model)
SE3	How the properties of materials may be explained (by their structure)
SE4	The interdependence of living things
SE5	The chemical cycles of life (carbon, nitrogen, etc.)
SE6	Cells as the basic units of living things
SE7	Maintenance of life (major life processes and systems)
SE8	The gene theory of inheritance
SE9	The theory of evolution by natural selection
SE10	The germ theory of disease
SE11	Energy sources and the idea of energy transfers
SE12	The idea of radiation
SE13	Radioactivity
SE14	The structure and evolution of the Earth
SE15	The structure of the Solar System
SE16	The structure and evolution of the Universe

In a similar way we can identify the Ideas about Science that we want students to learn. A striking feature of media coverage of science is that many stories are about risk and the factors that increase or reduce a given risk. Often claims are made about correlation and cause. The majority of these stories are about health and medicine. The sciences involved – epidemiology, health science, medicine – have not traditionally been part of the school science curriculum, which has centred on physics, chemistry and biology. The methods of investigation used in the health sciences (searching for correlations in large databases, clinical trials, etc.) have not normally been taught. But there is clearly a very strong case for including them. Here a scientific literacy emphasis involves introducing some new content. The *Ideas about Science* included in *Twenty First Century Science* are summarised in Table 2. Again more detail can be found in the course specification (OCR, 2008).

Table 2. 'Ideas about Science' in the *Twenty First Century Science* course

		Students should:
IaS1	Data and its limitations	be aware that all observations and measurements are subject to uncertainty; know how to use the mean and the range of values in a data set to assess its trustworthiness
IaS2	Correlation and cause	be able to think about phenomena in terms of factors (or variables) and an outcome (or the probability of an outcomes); know how a claim that a factor affects an outcome can be tested; be aware that correlation does not necessarily indicate cause.
IaS3	Developing explanations	be able to distinguish data and explanation in an account; aware of the role of imagination in devising explanations; know how explanations are tested by comparing predictions with data; be able to assess the implications of specific data for a given explanation
IaS4	The scientific community	be aware of the role and importance of peer review and the replicability of findings; be able to explain why people may reasonably reach (and defend) different explanations of the same data, and how external (non-scientific) influences may influence people's views and interpretations.
IaS5	Risk	be aware that all activities and processes carry some risk.; know how risks can be assessed and compared; be aware that measured and perceived risk can differ, and of the need to balance probability of occurrence and scale of consequences in taking decisions.
IaS6	Making decisions about science and	be aware of the benefits of science-based technology, and also the possibility of unwanted consequences; know some ways in which scientific activity is regulated; be able to identify costs and benefits

technology	of an action, separate issues of feasibility (can it be done?) from those of value (should it be done?), and discuss rationally science-related issues that have an ethical dimension.

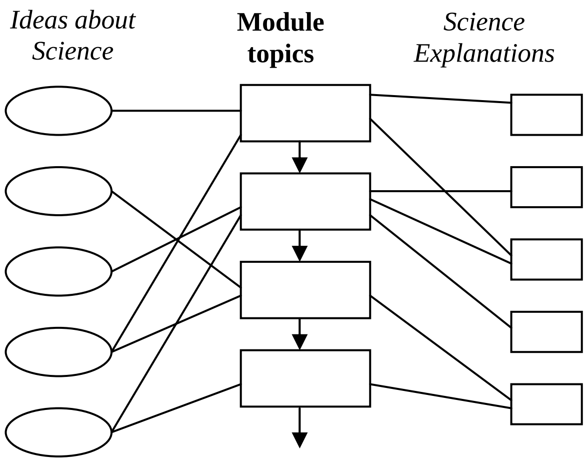
These two elements, *Science Explanations* and *Ideas about Science*, are the 'pillars' of the *Twenty First Century GCSE* Science course. The aim, however, was not to teach them out of context, but rather to develop an understanding of them through having students consider and discuss a series of issues, grouped around a small number of themes that would be of interest to many young people of this age. This led to a set of nine thematic modules (Table 3).

Table 3. The thematic modules that make up the *Twenty First Century* GCSE Science course

B1	You and your genes
C1	Air quality
P1	The Earth in the Universe
B2	Keeping healthy
C2	Material choices
P2	Radiation and life
B3	Life on Earth
C3	Food matters
P3	Radioactive materials

Figure 2 then illustrates schematically the structure of the GCSE Science course: a sequence of thematic modules, each of which develops understanding of one or two specific *Science Explanations and Ideas about Science*, planned in such a way that the whole sequence of nine modules allows students to meet each of the *Ideas about Science* more than once, so that they can see how these can be applied to many situations and contexts. There are in fact many more opportunities for re-visiting the *Ideas about Science* during the course, if teachers choose (or have time) to do so.

Figure 2. Structure of the *Twenty First Century* GCSE Science course



Because of its emphasis on becoming a more ‘critically aware’ consumer of scientific knowledge claims, the *Twenty First Century GCSE* Science course includes several case studies of current and historical episodes in which knowledge claims have been advanced, contested and perhaps resolved. These are used to open up discussion of epistemological issues, of the role of the scientific community, and of the issues (technical, economic, social, political, ethical) raised by the application of scientific understanding in new artefacts, materials and processes. Some examples are shown in Box 1.

Box 1. Examples of the use of case studies in Twenty First Century *GCSE Science*

You and your genes: A short video clip of a role-play (by professional actors) of a middle aged couple discussing symptoms the man has been experiencing which might indicate Huntington’s disease. Leads into discussion of the issues for various family members raised by a diagnosis, and whether this knowledge is beneficial. Develops the need to understand underlying genetics ideas to assess the issues involved. Later lessons in the module use real TV news clips about early diagnosis of cystic fibrosis to open up discussion of the arguments concerning the costs and benefits of screening programmes for genetic conditions.

Air quality: Data from air quality monitoring in urban environments is used to open up discussion of the replicability and reliability of measurements. Pollutants from vehicle engines are used as the context to develop understanding of the atomic/molecular model of chemical reactions and reinforce the idea that no atoms are created or destroyed in such processes.

Radiation and life: Data and information on the risks and benefits of UV in sunlight are presented. This provides a context for reinforcing key ideas about radiation (spreading out with distance from a source; possible consequences when absorbed, etc.). Also leads to discussion of risks of microwave radiation, and how related health studies might be made more convincing (large samples; better matched samples; better control of other variables, etc.)

Case studies are valuable not only in providing contexts for introducing scientific explanations and ideas about science, but also opportunities for discussion and debate in science classrooms. Several recent studies (Lyons, 2006) have identified the absence of such opportunities, and the consequent perception by students of science classes as 'one way transmission of factual knowledge from teacher to learner, as a major source of student disaffection with school science. Discussion of issues, which many students find engaging, can increase students' motivation to come to terms with abstract ideas and specialist terminology, and acts as a powerful reminder of the links between taught science ideas and the issues one hears about outside school. Students also need to come to realise that everyone is entitled to have and to express a view about such issues, but that views are more persuasive when they are grounded in sound understanding of the underlying science and follow established patterns of argumentation (for example, using systematic evidence rather than anecdote, or using an accepted general form of argument about ethical action). In this, as in much else, practice is important – and science classes can play a role in getting students used to analysing the arguments of others and constructing sounder arguments of their own.

The teaching materials produced for the *Twenty First Century Science* pilot included full-colour textbooks, files of photocopyable resources for each lesson with accompanying teachers' notes, and an iPack (a CD-ROM containing a collection of computer-based resources: video and audio extracts, animations to help teach some key ideas, Powerpoint presentations and so on). A project website was developed to support pilot school teachers. The project also provided training for teachers in using the course materials, with a particular emphasis on new or unfamiliar content and on teaching methods that are less commonly used in science lessons (such as discussion of open-ended issues, use of newspaper articles as resources).

The outcomes of the pilot trial

There is not space in this paper to provide a full account of the outcomes of the pilot trial of *Twenty First Century Science* so what follows is a brief summary. During the pilot, the project team collected data on teachers' views of the course and of their students' reactions to it, in both formal ways (though questionnaire surveys) and more informal ones (feedback sessions and individual conversations during training workshops and school visits). Millar (2006) summarises the main findings of this internal evaluation.

They paint a very positive picture of teachers' reactions to the course, with many believing it had improved their students' scientific literacy and had led to significantly higher levels of student engagement and interest. Apart from the challenge of getting used to a new course and new activities, the main problems teachers identified were the amount and level of reading involved in some activities, and in managing discussions in class, especially of issues with no single correct answer. The project worked with teachers during the pilot to try to address these difficulties, by developing modified teaching materials with lower language demand and targeting training on teaching approaches that were proving more challenging

The project also commissioned three formative evaluation studies by researchers outside the development team, and engaged another experienced science educator to maintain an overview of this work and write an overview of the findings. The studies looked only at the core GCSE Science course within the *Twenty First Century Science* suite, and focused on classroom implementation, teachers' and students' views of the course, evidence of changes in students' attitudes to science, and the development of students' understanding of some of the *Science Explanations and Ideas about Science.* The overview (Donnelly, 2007) and executive summaries of the three studies are available from the project website (www.21stcenturyscience.org). In brief, these studies reported a positive teacher and student response, no significant difference in students' level of understanding of science content as compared to 'traditional' courses, some evidence of greater interest in reading about science among students who had followed the course, and – perhaps most importantly – the continuing need for support and training for teachers to improve their understanding of the course aims and their confidence with the new teaching styles involved. There was also evidence that teachers' understanding of the course, and ability to teach it well, had improved considerably over the two years of the pilot, but still needed, in many cases, to improve further.

While the pilot was in progress, QCA announced its intention to introduce changes in GCSE course specifications from 2006, requiring that all courses have a 'core + additional science' structure. It therefore became necessary to review and amend the pilot materials sooner than had been planned and on a much tighter time scale, so that a revised course could be made available to schools for use from September 2006. This work was, however, successfully completed and a revised *Twenty First Century Science* course, significantly modified in the light of the experience of the pilot, and benefiting from many suggestions and ideas from pilot school teachers, was published in 2006

(Twenty First Century Science, 2006). *Twenty First Century Science* is now in use in around 1100 schools, or 25% of maintained (state) secondary schools in England, with over 120 000 students completing the first full post-implementation cycle in July 2008.

What have we learned?

The *Twenty First Century* GCSE Science course is, of course, just one response to the challenge of teaching science for scientific literacy. There any many other possible ways of interpreting this challenge and responding to it. The value of a concrete response – in the form of a fully articulated teaching programme, with textbooks and other support materials – is that it enables the developers to communicate their vision more clearly, and makes it easier for other science educators to assess and evaluate its potential for their own situation. Some of the design criteria used in developing *Twenty First Century* GCSE Science seem fundamental to any scientific literacy course. Amongst these are: seeing the learner as a consumer, rather than a potential producer, of new scientific knowledge; and aiming to teach some science content (accepted scientific knowledge) and also something about science itself (the nature of science and scientific enquiry).

Beyond that, however, choices and emphases might well differ. The hope of the team that developed *Twenty First Century Science* is that it will stimulate other developments that will provide the international science education community with a range of worked examples of scientific literacy courses – so that we are better able to assess the potential of such courses, and gain a better understanding of the challenges of developing and implementing them.

The development of the teaching materials for the *Twenty First Century Science* pilot was essentially a test of the feasibility of the curriculum design outlined above. Our work has shown that it is possible to design a course with the structure shown in Figure 2, which is workable and attractive to many teachers – something which we did not know when we began. The evidence from the pilot and from the first two years of more general use of the course is that a scientific literacy emphasis can significantly improve students' engagement with science ideas and issues, in schools where teachers have a sound understanding of the rationale for the course and are generally supportive of its aims and aspirations.

This is not, however, a quick or easy 'fix' for the problems of student engagement that arise in many countries. We need to begin to change the curriculum for younger learners too, not just for 15-16 year olds. And we need to be aware of the demands that new ways of teaching put on science teachers, and provide effective support for them in making the changes that many wish to make. The Head of Science in one *Twenty First Century Science* pilot school wrote:

> "I know that my students are better prepared for A-level. Their understanding of difficult concepts is much better. In the unit on electricity, for example, … my former students would know the formulae and rote definitions, but not understand what was happening in a circuit."

But he also went on to make an observation about the demands on teachers' expertise:

> "*Twenty First Century Science* is harder to teach, you need to be more creative in producing practical activities, you need more access to ICT [information and communications technology] and the coursework takes a good, strong teacher to manage well. But from the eyes of students it is a universe ahead of anything else."

It is that final comment (and others like it from many teachers involved in this development) that encourage us to think that teaching science with a scientific literacy emphasis can lead to a significant change in our students' engagement with the world of science.

Acknowledgements

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