Developing a Science Curriculum to Foster Scientific Literacy

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Introduction

In many countries, there is growing concern about the quality and effectiveness of school science education. A decreasing proportion of young people are choosing to study science, particularly the physical sciences, in upper secondary school and at university level (see, for example, Roberts, 2002; European Commission, 2004). Research studies in a range of countries also show consistent evidence of a decline in students' attitudes towards school science during the secondary school years (Bennett, 2003). In the ROSE (Relevance of Science Education) project survey, students in developed industrial countries indicate that they like science less than other school subjects, and relatively few aspire to careers in science (Sj■berg and Schreiner, 2005). Whilst many agree that science is important, they feel it is 'not for them' (Jenkins and Nelson, 2006). Data from the TIMSS and PISA studies show that there is no positive association between achievement in science and students' attitudes towards the subject. Indeed, countries with the highest average achievement scores tend to have the lowest proportion of young people with a more positive attitude towards science as a subject and as a potential career. The ROSE survey data takes this analysis a stage further, by showing a negative correlation between a country's level of development (using the United National Human Development Index) and the proportion of students with positive attitudes towards science. This suggests a mismatch between the image of science presented in school science courses and young people's sense of identity in the modern world - and an urgent need to review the way we present science as a subject within the school curriculum.

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. In essence, 'scientific literacy' is a shorthand for "what the general public ought to know about science" (Durant, 1993: 129). This has led some to suggest that current talk of 'scientific literacy' is simply old arguments in a new guise; DeBoer (2000), for example, suggests that "to speak of scientific literacy is simply to speak of science education itself" (p.582). Bybee (1997) points to the value of 'scientific literacy' as a slogan; as "a rallying cry for contemporary reform, it serves to unite science educators behind a single

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statement representing the purposes of science education"(p.71). The term 'scientific literacy', however, also signals a distinct change of emphasis, away from science courses that aim 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 (including those who may become the scientists of the future) require.

One reason why this shift of emphasis matters can be seen by simply counting numbers. As Ogborn (2004) points out:

> "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." (p.69)

In other words, 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 intelligent and better informed consumers of scientific information, in the forms in which they encounter it in everyday life. 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. But this 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.

An opportunity to test a new approach

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.

There were some significant precursors to this work. In particular, the *Beyond 2000* report (Millar and Osborne, 1998), arising from a seminar series funded by the Nuffield Foundation to discuss issues and options for school science in the twenty-first century, had sketched out ideas for the design of a curriculum with a 'scientific literacy' emphasis. This in turn drew on an earlier paper by Millar (1996). As regards general principles, *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. The policymakers' decision to implement a pilot trial was influenced by the perceived success of a recent course development for students in the upper secondary school (age 17-18), based on similar design principles, the Advanced Subsidiary (AS) level course *Science for Public Understanding* (AQA, 2008; Hunt and Millar, 2000; Millar and Hunt, 2002).

For students up to the age of 16, the science programme on offer in 2002 was based on the national curriculum first introduced in 1989. 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 total) were called Double Award General Certificate of Secondary Education (GCSE) Science, as they were equivalent to two normal GCSE subjects. A much smaller number of students (around 10%), mostly those of lower academic attainment, took just a single GCSE Science, following a programme devised rather hastily in 1989 by selecting 50% of the content of the majority Double Award programme. A similar number, mainly higher achieving students, took three GCSEs in Biology, Chemistry and Physics.

The curriculum model that QCA wished to pilot proposed dividing the 20% of curriculum time normally 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 also take one of these. The suite of courses based on this model became known as *Twenty First Century Science*.

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***

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

This model implicitly made the very important statement that all students should continue to study some science to the age of 16 - a position which some influential voices were known at the time to be calling into question. But it followed this with the assertion that this core course therefore must offer a form of scientific knowledge and understanding that can be seen to be of benefit to all students, not just to those who might aspire to take more advanced science courses. Separating the two aims of the science curriculum allowed each of the component courses - the core Science course and the Additional Science courses - to be designed to fit its specific purpose. By making Additional Science a course that students opt to take, we believed that this could be made more stimulating and challenging than existing Double Award Science - and would provide a better basis for progressing to more advanced study for those who chose to do so. Also, the modular structure made for greater flexibility when seen from the perspective of lifelong learning; any student who chose to take only the GCSE Science course at age 15, and came to regret this, could easily pick up one of the Additional Science GCSEs later.

QCA appointed Oxford, Cambridge and Royal Society Examinations (OCR) to develop the formal specification (or syllabus), to manage the examining and assessment process, and the award of GCSE certificates to successful candidates. Alongside this, but independent of it, the University of York Science Education Group (UYSEG) and the Nuffield Curriculum Centre obtained significant funding from three charitable trusts (the Salters' Institute, the Nuffield Foundation, and the Wellcome Trust) to develop teaching materials and a programme of support and training for teachers involved in the pilot.

In early 2003, QCA then issued an open invitation to schools to participate in a pilot trial of the *Twenty First Century Science* curriculum model, beginning in September 2003 and running for three school years (so that two cohorts could complete the courses). A total of 78 schools applied and all were accepted. They included schools with and without Sixth Forms (the senior two years of the secondary phase), in a mixture of urban, suburban and rural settings, widely distributed throughout England. As a group, they were broadly representative of maintained (state) schools in England. Around 6000 students completed the core Science GCSE course in each of the two pilot cohorts, with somewhat smaller numbers completing each of the Additional Science courses.

It is, of course, one thing to say that a course will have a 'scientific literacy' emphasis and try to develop the kind of understanding of science that all young people, future scientists and non-scientists alike, will 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 will outline the design of the core Science course that was developed.

Designing a science course to foster 'scientific literacy'

Whilst the term 'scientific literacy' is nowadays widely used, there is no agreed definition of its meaning or its implications for the school curriculum. Most science educators, however, see 'scientific literacy' in terms similar to those of the authors of the US National Science Education Standards, who characterise 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)

So what knowledge and capabilities are needed in order to do these things? 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 work towards an answer 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 explicitly 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. The *Beyond 2000* report (Millar and Osborne, 1998) used the metaphor of a 'story' to try to capture the kind of understanding required - we want students to be able to use the explanation in their own discourse, rather than simply recalling fragments of knowledge.

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 (largely for historical reasons) centred on physics, chemistry and biology. The

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

methods of investigation which the health sciences use (searching for correlations in large databases, clinical trials, etc.) are not normally taught. But there is clearly a very strong case of 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).

These two elements, *Science Explanations* and *Ideas about Science*, are the 'pillars' of the *Twenty First Century* GCSE Science course. They are introduced and developed through a set of nine thematic modules, on topics chosen to be of interest to students aged 15-16 (or in which it would be relatively easy to interest such students) (Table 3).

Figure 2 then illustrates schematically the structure of the GCSE Science course: a series of thematic modules, each of which introduces or develops understanding of one or two specific *Science Explanations* or *Ideas about Science*. Each of these is encountered at least twice as you work through the set of nine modules - and there are many more opportunities for reinforcing the *Ideas about Science* in particular, if teachers choose (or have time) to make use of them. This 'revisiting' is particularly important for *Ideas about Science*, where the aim is to help students appreciate that these apply to many science topics and issues, and not only to the contexts in which they have been taught.

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

Table 2. *Ideas about Science* in *Twenty First Century Science*

IaS1	Data and its limitations	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	Can think about phenomena in terms of factors (or variables) and an outcome (or the probability of an outcome); know how a claim that a factor affects an outcome can be tested; aware that correlation does not necessarily indicate cause.
IaS3	Developing explanations	Can 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; can assess the implications of specific data for a given explanation
IaS4	The scientific community	Aware of the role and importance of peer review, and of replicability of findings; can 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	Aware that all activities and processes carry some risk. Know how risks can be assessed and compared, and aware that measured and perceived risk can differ. Aware of the need to balance probability of occurrence and scale of consequences in taking decisions.
IaS6	Making decisions about science and technology	Aware of the benefits of science-based technology, and also the possibility of unwanted consequences. Know some ways in which scientific activity is regulated. Can identify costs and benefits 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.

Table 3. 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

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.

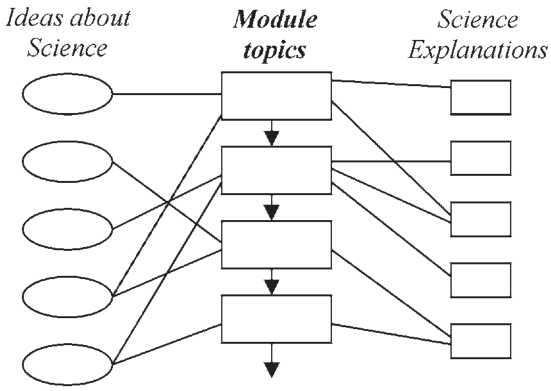

Figure 2. Structure of the *Twenty First Century* GCSE Science course

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 ordestroyed 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 (through questionnaire surveys) and more informal ones (feedback sessions and individual conversations during training workshops and school visits). Millar (2006) presents 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 they experienced were the amount and level of reading involved in some activities, and 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 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 their findings. The studies focused on the core GCSE Science course within the ***Twenty First Century Science*** suite, and looked at classroom implementation, teachers' and students' views of the courses, evidence of changes in students' attitudes to science during the course, and the development of students' understanding of science content 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 measurable 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.

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 inputs 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 expected to complete the first full post-implementation cycle in July 2008.

What is generic and what is particular to this development?

Any science course development has to begin with some general design principles and then devise ways of implementing these with the particular content chosen. From the course and the detailed teaching materials produced it can be difficult to see what is thought by the designers to be fundamental to the design of any scientific literacy course, and what is more contingent and could have been done differently. It might be useful briefly to try to distinguish the two in the case of the *Twenty First Century* GCSE Science course. Seeing the learner as a consumer, rather than a potential producer, of new scientific knowledge seems fundamental to any course that aims to foster scientific literacy. This leads directly to the primary aim: to help learners become more discerning consumers. I would also argue that any scientific literacy approach at school level must aim to teach some science content (accepted scientific knowledge) and also something about science itself (the nature of science and scientific enquiry). However, different choices might be made about which aspects of scientific knowledge and which ideas about science to include, and how deeply into them the course should go. Also, the way in which the two central elements are put together to form a coherent course (as in Figure 2 above) could vary widely, as could the choice of contexts and examples to use to gain and hold students' interest, and the suggested classroom activities. It might, for example, be possible to structure a scientific literacy course around the competencies that we wanted students to develop; in *Twenty First Century Science* these are implicit in the course design rather than being explicit structural features. The team that developed *Twenty First Century Science* see it as showing one way of developing a course to foster the scientific literacy of 15-16 year-old students, not as showing the way. Indeed we hope that it will stimulate other developments that will then provide the international science education community with a wider and richer range of worked examples of scientific literacy courses, that will help us to assess the potential of such courses, and the challenges of developing and implementing them.

What have we learned - and what remains to be done?

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. It 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. The evidence from the pilot is that a scientific literacy emphasis can significantly improve students' engagement with science ideas and issues, though it is too early to say if this is replicated in the very much larger number of schools using the course in the post-pilot phase, where many teachers have a less clear understanding of the rationale for the underlying curriculum model and the 'flavour' and design of the component courses than in the pilot. Further studies of the impact of the courses, following their wider adoption from 2006, are planned. We are interested to know more about how schools make use of the greater flexibility in matching science courses to students that was the starting point for the development, and about how students are responding to the 'scientific literacy' emphasis of the core GCSE Science course.

We have anecdotal evidence that the combination of GCSE Science and GCSE Additional Science works for students who want to progress to more advanced study. In a recent email, the Head of Science in one pilot school wrote:

> "I know that my *Twenty First Century Science* 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."

We need, however, to collect much more systematic evidence on the effectiveness of this combination of courses, and of Science plus Additional Applied Science - and on the subject choices in the upper secondary school of students who have taken them.

Finally there is the issue of implementation. The Head of Science quoted above went on to say:

> "*Twenty First Century Science* is harder to teach, you need to be more creative in producing practical activities, you need more access to ICT 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."

This highlights the challenge of teaching science with a scientific literacy emphasis. New ways of teaching science make new demands on teachers, and training and support are essential to enable them to implement a course like *Twenty First Century Science* well. This is perhaps the clearest and most consistent message from the various evaluations of *Twenty First Century Science*. The prize, however, if we can get it right, is a significant change in students' engagement with the world of science.

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