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The Challenge of Teaching About Ideas and Evidence in Science

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This booklet, and the associated CDROM, is intended as a resource-bank of ideas, approaches and activities to help teachers when teaching about 'Ideas and Evidence' in science. The resource derives from a KS3 Strategy initiative set in an initial teacher education ('teacher training') context: however, we believe that the resource is likely to be of interest to all those teaching science, at whatever level and regardless of their own level of teaching experience.

The team that worked on this project believe that teaching about 'ideas and evidence' in science is very important. However, there is also a widespread view that this is one aspect of science teaching that is currently, speaking generally, not done very well in many schools. This is not to criticise teachers – as there are a number of very good reasons why teaching about 'ideas and evidence' has often been weaker than teaching about other aspects of science. This introduction suggests why 'ideas and evidence' has not been a strong feature of science education under the National Curriculum, and how the situation can be improved.

What is 'ideas and evidence' about?

The National Curriculum (DfEE/QCA, 1999) for England and Wales has four attainment targets, the first of which (Sc1) is 'scientific enquiry'. At Key Stage 3 (KS3, lower secondary level, i.e. 11-14 years) the curriculum document describes what is expected of pupils:

> During key stage 3 pupils build on their scientific knowledge and understanding and make connections between different areas of science. They use scientific ideas and models to explain phenomena and events, and to understand a range of familiar applications of science. They think about the positive and negative effects of scientific and technological developments on the environment and in other contexts. They take account of others' views and understand why opinions may differ. They do more quantitative work, carrying out investigations on their own and with others. They evaluate their work, in particular the strength of the

> evidence they and others have collected. They select and use a wide range of reference sources. They communicate clearly what they did and its significance. They learn how scientists work together on present day scientific developments and about the importance of experimental evidence in supporting scientific ideas.
>
> (DfES, 1999)

Sc1 is therefore about pupils learning about science as an activity or process (rather than learning about particular scientific topics - about the place of science in culture and society, as well as about 'doing' science.

The 'doing science' part is largely reflected in the strand of Sc1 called 'scientific investigations' which sets forth a simple model of experimental work in science (Kind & Taber, 2005). But 'learning about science' is more than learning to plan, execute and evaluate simple practical investigations, in the context of one-hour-or-so lessons in school laboratories. The broader aspects of appreciating what science is about, how it works, how it came to be as it is, and how it reflects and impinges upon the wider society, are reflected in the other strand of Sc1, known as 'ideas and evidence'. At KS3 pupils should be taught about the following aspects of 'ideas and evidence in science':

> a) about the interplay between empirical questions, evidence and scientific explanations using historical and contemporary examples [for example, Lavoisier's work on burning, the possible causes of global warming]
>
> b) that it is important to test explanations by using them to make predictions and by seeing if evidence matches the predictions
>
> c) about the ways in which scientists work today and how they worked in the past, including the roles of experimentation, evidence and creative thought in the development of scientific ideas.
>
> (DfEE/QCA, 1999)

Why is teaching about 'ideas and evidence' so important?

The 'ideas and evidence in science' strand of Sc1 is at the core of what is sometimes known as the Nature of Science. It could be argued that very little of the actual scientific knowledge in Sc2-4 is in itself that important for most pupils in terms of their likely future lives. Being argumentative, it could be claimed that in a technological society people need to understand how to use the products of science rather than why and how they work.

Of course there are aspects of science that it is important to understand, for example in terms of personal health and safety (although they may well appear in other places in a school's curriculum, such as PSHE – personal, social and health education). Even in these cases it is possible to learn about – for example – the importance of a balanced diet, and which foods are good sources of protein, vitamins etc, without really understanding much of the science involved. When it comes to operating the television remote, or the new laptop computer, it is possible to become effective users of the product without having much understanding of the scientific principles or the technical subtleties.

It is probably even the case for those who go on to work in science-based and technology-related careers, that they usually only draw on a small proportion of the science they met in school in their work. As most people do not aspire to such careers it is more important to ask what kind of science is needed to be an effective citizen in a technological society (Millar & Osborne, 1998).

So we can largely operate effectively in the modern world with only a small minority of the population understanding the technical details of how things work. Even research scientists are likely to have little practical expertise outside their own areas: it is unlikely that a geneticist could mend the TV remote if the electronics became damaged, or that a nuclear physicist would recognise an endangered species of fish or insect. We therefore need to ask 'which aspects of science really justify their place as a core component of the curriculum'.

There are probably two areas where we would seek scientific literacy for all our pupils. Both concern informed decision-making. The first involves the personal decisions that we all make – such as to purchase the more expensive shampoo with the amino acids added, to recycle our waste paper, to use a particular method of 'family planning'. The second concerns the individual's role in a democracy, campaigning or voting on issues such as nuclear power, hunting whales, embryonic stem-cell research, or – to take an extreme but tragically very real case – supporting a party espousing 'racial purity'.

In all of these areas, whether selecting brands of toothpaste, balancing the costs and benefits of forms of electrical power generation, or recognising the notion of human races as a cultural and not a scientific construct, decisions need to be made. In order to make decisions effectively, people need three things that education can help develop: a set of personal values, the ability to think rationally, and the capacity to obtain, and evaluate, evidence.

It is arguable whether science is a subject that should look to help determine pupils' value systems. Science cannot tell us whether it is right to eat animals, to fight wars, to lie to and betray our friends for personal gain, or to channel disproportionate levels of resources to those identified as an elite. However, science can help us learn how to clarify and explore our values, and how to apply them in informed and logical ways.

Science can help us learn how to find out about the consequences of potential actions, and can help us evaluate the claims that are put before us: that nuclear power is dangerous; that butter/pasta/tomatoes/wine/cashews is/are good/bad for us; that global warming is just a theory and has not been 'proven'; that biodiversity is a luxury; that mother earth will protect us; or that those born Aries will come into money this week.

Why has 'ideas and evidence in science' not been taught well?

The present project was initiated for the Key Stage 3 Strategy because 'ideas and evidence in science' has been identified as an aspect of science teaching where there is 'room for improvement' – i.e. that it is 'currently underdeveloped in many schools'. There is certainly some very good practice, but, generally speaking, secondary science teaching should put a greater emphasis on this aspect of the curriculum.

However, there are a number of reasons why learning about ideas and evidence in science has been a relatively weak aspect of many pupils' schooling:

1. Most teachers learnt relatively little about the 'nature of science' in their own schooling, or in their own degree studies;
2. This is an area that has not been widely emphasised in teacher education in the past;
3. It is expected that Sc1 will be taught through the context of Sc2-4, where simply teaching the curriculum models of biology, chemistry and physics often makes enough demands of the teacher, without considering how those ideas came about, or the extent to which they can be considered 'reliable knowledge';
4. Many teachers feel that the secondary science curriculum is content-heavy, so that time is limited and has to be carefully apportioned;
5. The aspect of Sc1 that has seemed to be a priority has been 'scientific investigations'.

Until recently formal assessment in Sc1 has seemed to mean the assessed investigations pupils undertake, and naturally teachers – under time pressures, and perhaps feeling that they are poorly prepared to explore the philosophy and history of science – have tended to prioritise their teaching of Sc1 in this area. We are pleased to see that 'ideas and evidence' is now receiving more attention as an area for assessing pupils (QCA, 2002), but recognise that teachers need more support in preparing to teach this area. We hope this SEP resource will be of value here.

Some teachers, undoubtedly, do feel they already do a good job teaching about the nature of science. We are sure there are many teachers who incorporate, for example, stories about key historical developments, in their teaching in Sc2-4 so that their pupils get a feel for the way science works.

Yet the research that has been undertaken in the past (e.g. Driver et al., 1996) suggests that most secondary age pupils have a very limited appreciation of the nature of science. For example, students may feel that experiments can unproblematically turn a hypothesis into a 'proved theory', and that a model is always a scaled-up or scaled-down replica of something like a cell or a solar system.

It may be revealing for teachers to ask their own classes about their understanding of key terms used in science (such as 'theory' and 'experiment'). As part of one of the projects discussed here, some KS3 pupils in top science sets were asked about their understanding of key terms, and the probe used is included on the CDROM for any teachers who wish to try this with their own class (see the material on 'Exploring the Curriculum Model for teaching about the Nature of Science' included on the CDROM).

The context for teaching about ideas and evidence

Although we would argue that Sc1 might represent the most important part of a science education, we are certainly not suggesting that pupils should not be taught about science topics such as, for example, photosynthesis, the periodic table or Hooke's law. The vast scientific knowledge on which our modern society depends is a central part of our culture, and we feel that an understanding of how the world works is important as well as an understanding of how we come to know how the world works. However, judgements about which aspects of scientific knowledge should be taught are likely to change (for example, the KS4 curriculum is under review at the time of writing) where understanding about the processes of science is always going to be important.

In any case, it is not possible to effectively teach about ideas and evidence in science, without looking at some ideas and evidence! What is photosynthesis, and how do we know it requires sunlight? Why do we think the periodic table is a good way of organising our ideas about the elements? How convincing is the evidence that the extension of a spring is proportional to the load attached?

At present, many pupils are learning science as isolated fragments of knowledge, and this does not allow them to appreciate how ideas come about, or how they may not always apply, or why they may not always lead to precise predictions. Pupils often see theories as facts, which have been proven, because science is often presented that way. If pupils could spend more time seeing how ideas develop, and how they change, they would better appreciate the nature of scientific knowledge, and the great cultural achievements of science.

Failing to appreciate the nature of science also limits how well pupils can understand the science that they are taught. Not appreciating the extent to which many scientific ideas are models means that pupils do not appreciate their limitations, nor how they are open to be being developed or even discarded. This can be very frustrating for pupils when they feel they are being asked to 'unlearn' a model they had been taught earlier in their education.

The KS3 Strategy/SEP Project

If teaching about 'ideas and evidence in science' is recognised to be a relatively weak aspect of secondary science teaching then it is likely that many of those training to be teachers see very limited good practice on which to model their own teaching. Cleary this is potentially a vicious circle, as these new entrants will become the role models and mentors for future trainees.

The KS3 Strategy invited Universities involved in initial teacher education ('teacher training') to consider being part of a project to "enrich existing initial teacher education and training about the Ideas and evidence in science aspect of Scientific Enquiry (Sc1) [that] should also have the potential to contribute to the professional development of more experienced teachers of science." It was hoped that the project would help focus the minds of the teacher educators, trainee teachers, and their school-based mentors on the issue of teaching about ideas and evidence in science, and lead to projects that would both augment the teaching repertoires of those directly involved and also have the potential for wider dissemination.

Five universities were invited to develop their responses to the invitation into supported projects (Cambridge, Keele, King's College London, the London Institute of Education and York). Each project is being reported on the KS3 website with an outline of the work undertaken.

The **Science Enhancement Programme** (one of the charitable Gatsby Foundation's Technical Education Projects) has provided additional support in three ways:

- By providing additional financial support for the projects;
- By providing a forum where the project leaders in the five universities could meet to discuss their work;
- By publishing and disseminating the present resource, to make the outcomes of the projects widely available.

The five university-based projects all took a 'teacher education' perspective to look at teaching about ideas and evidence in science. However, each had its own flavour, with different priorities, foci, and modes of operation. The outcome is a set of materials that provides teachers with a range of ideas, activities and approaches to explore and develop pupils' understanding of ideas and evidence in science.

An invitation to teach about science…

The CD accompanying this booklet includes a range of material developed by the five Universities with their partners in schools and LEAs. We hope that readers, whether new teachers or more experienced, whether confident or apprehensive about teaching 'ideas and evidence in science', will find something here to give them pause for thought, as well as some ideas for enriching their own teaching.

References

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