TEACHING SCIENCE IN A MULTICULTURAL, MULTIFAITH SOCIETY

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Introduction

Just suppose that the following three statements are true:
- there is no doubt as to what science is;
- the role of teachers of science is to teach pupils what science is;
- science teachers do not need to take much account of pupil diversity in their classrooms because all pupils of a certain age and ability come to science lessons with much the same knowledge and understanding of, interest in, perceptions of and expectations of science.

Well, the job of a science teacher would be a lot easier, wouldn't it? Mind you, it would be a lot less satisfying for a creative teacher. This chapter is written with the conviction that none of these three statements is true and that by analysing further why these statements misrepresent pupils, science and the job of teaching, science teachers and science educators can be helped to find richer ways of teaching science in schools at both primary and secondary levels.

I will try to answer four questions. The first three relate to the three bullet points above; the last is to do with one aspect of teaching science in a multifaith society:
- What is science?
- What are the functions of science teachers?
- Why do science teachers need to take account of pupil diversity and how can they do so?
- Should questions to do with scientific origins - of the Universe, of life and of the human species - be introduced in science lessons and if so, how?

Aspects of the first three of these questions are also considered from different angles in other chapters in this book. But they need to be considered here to prevent multicultural science being seen by some as a sort of marginal extra in science education, something that it would be nice to do if we had the time and resources or if we had a different sort of pupil intake.

What is science?

For a start, there isn't science; rather, there are sciences and there are ways of undertaking science. World-wide, many school science curricula pay, at best, lip service to this. For example, ever since the introduction of the National Curriculum in England and Wales in 1989, the notion that there is a single best way of carrying out a scientific investigation has been enshrined in legislation. Although the 1995 revision of the science National Curriculum slightly improved affairs, it remains the case that most pupils end their mandatory science education (sometimes overenthusiastically referred to as their 'entitlement for science education') with a very narrow understanding of what science is and how it is carried out (Driver et al., 1996; Donnelly and Jenkins, 1999).

Let me be personal. In my own, brief, career as a research scientist, I worked in the Zoology Department of a reputable university. Yet I carried out two quite different types of scientific work. One involved field work on the behaviour of red deer. Here, being a good scientist meant such things as being able to find particular deer (which might take an hour or more), identify them, record their behaviour using techniques adapted from field anthropology and so on. The other type of scientific work involved constructing mathematical models to try to predict why animals were the size they were. Trying to explain why both types of work could be carried out in the same Zoology Department is quite difficult. Apart from the fact that each involved original work on animals they had little in common. Interestingly enough, neither bit of work would have got me a high level on Attainment Target 1 (Sc1) of the Science National Curriculum. Authors who have argued for the need for and feasibility of having pupils conduct genuine classroom investigations include Woolnough (1994), Albone, Collins and Hill (1995) and Roth (1995).

Writers about multicultural science often include something about the nature of science to try and persuade the reader that pupils generally leave school with only a narrow model as to what science is. Indeed, historians of science, sociologists of science, philosophers of science and a growing number of science educators accept that there is no such thing as 'science' or 'the scientific method' (e.g. Feyerabend, 1988; Woolgar, 1988; Chalmers, 1990; Aikenhead, 1997).

For example, the current strong consensus amongst historians of science is that what we call science has changed greatly over the centuries. Fascinatingly enough, this does mean that, in the words of two historians of science "On this view, the history of science becomes a relatively short and local matter: extending back less than 250 years, and largely confined to western Europe and America" (Cunningham and Williams, 1993: 429).

Now, at first sight, such an assertion seems to fly in the face of what writers about multicultural science (including myself) commonly maintain, namely that other cultures have had flourishing examples of science that should be much more widely known by pupils (Peacock, 1991; Solomon, 1991; Reiss, 1993; Thorp, Deshpande and Edwards, 1994; Reiss, 1998). However, this 'de-centring the Big Picture' can serve to free up school science education. Instead of comparing the scientific achievements of other cultures against the canons of late twentieth century Western science, pupils can be helped to see that science is a cultural activity and that thus it is, inevitably, the case that different cultures produce different sciences.

There are two main reasons, I think, why such an apparent innocuous assertion can prove so disconcerting, even unbelievable or threatening, to many science teachers. One is simply that most of us were not taught, at school, a view of science which saw it as a cultural activity. The implicit message we were given was that, to parody Hebrew 13:8, 'Science is the same yesterday and today and for ever'.

The second reason why the notion that science is a product of human culture can be so troublesome is that it can appear to give credence to a theory of absolute relativism. It may be thought that once it is admitted that scientific truth is culturally bound rather than absolute (i.e. the same for all times and in all places) this is not only to eschew a doctrine of logical positivism or scientism but to embrace a belief that scientific 'truth' is meaningless.

A way out of this apparent dichotomy is to steer between Scylla and Charybdis, lashing oneself to the mast of reliable knowledge. In other words, science provides only provisional truths but nevertheless these truths are often robust. This is most obviously the case when considering how we can use well established laws in physics and chemistry to determine, for example, how much fuel an aeroplane needs for a flight. But even in contemporary areas of public debate science can often help. For instance, we can't yet be certain about the long-term health consequences of our eating genetically modified foods (how could we be?!) but the knowledge provided by feeding such foods to two or more generations of rats provides information which is trustworthy to a certain extent.

What are the functions of science teachers?

The question of the functions of science teaching has been extensively debated in recent years both in the UK and internationally (Black and Atkin, 1996; Millar 1996, Millar and Osborne, 1998). Increasingly, it has been agreed - largely for reasons to do with justice rather than with the design of school curricula or with pedagogy - that school science education should serve the needs of the whole school population. That is, it cannot exclusively or even primarily restrict itself to the interests of that small minority of pupils who will go on to become scientists.

For this reason, scientific literacy, however this term is construed, is seen as the prime aim of science teaching (see also Layton et al., 1993; Irwin and Wynne, 1996). Generally, scientific literacy is seen as being a vehicle to help tomorrow's adults to understand scientific issues. In the UK, for example, it is thus hoped that a good school science curriculum might help us to understand the uncertainties around BSE or global warming. (As a parenthesis it can be noted that such topics generally sit more in biology than in chemistry or physics. However, in the UK an uneasy alliance between biology, chemistry and physics educators has meant that, to date, the notion that the science curriculum must contain equal portions of these three sub-sciences has been treated as a law of the Medes and Persians.)

I am fully in agreement with this understanding of scientific literacy, as far as it goes. But it can be taken further by considering the three axes of 'the here and now', 'space' and 'resistance'.

For a start, we should not only think of school science education providing skills and information for the citizens of tomorrow; it should be absolutely relevant to the pupils being taught today, i.e. in the here and now. Obvious examples of topics pertinent to pupils that could be meaningfully taught in school science include ones presently covered (though often in only a rather cursory fashion) in health education and environmental education within science.

For example, the issue of cigarette smoking is typically, in my experience, covered in school science lessons by means of a practical demonstration that cigarettes contain tar and a serious of polemics (often backed up by the making of posters by pupils) that smoking is bad for you. More time in science curricula would allow for both a more detailed and a more nuanced treatment. For instance, pupils could be taught more about the addictive nature of nicotine, about possible health benefits of smoking (e.g. there is some evidence for a negative relationship between the risk of developing Alzheimer's disease and the number of cigarettes smoked) and about the reasons why people take up smoking. They could also, in science lessons, PSHE lessons or citizenship lessons, consider whether the aim of education about smoking should be one of beneficence (doing good, e.g. by persuading pupils not to smoke) or one of the promotion of autonomy (i.e. enabling pupils to make their own informed choices) - see Reiss (1996). It would also be worth seeing whether pupils' writings could have audiences beyond their teacher and peers. For example, instead of only constructing posters about smoking, destined never to leave the confines of school laboratory walls, pupils could produce desk-top published leaflets for distribution in GP surgeries or, failing that, at least in the school visitor area.

A second way in which the notion that school science education ought to be for the benefit for the whole school population can be taken further is by accepting the idea that education can help provide pupils with space in which to live their lives. This idea has its roots in the work of Solomon (1992) who looked at how pupils learn about energy. She found that pupils do not simply learn a single meaning for the term 'energy'. Instead, they get to know about its several meanings in a variety of ways. Indeed, pupils are perfectly capable of holding a number of alternative understandings (nowadays they might be called 'mental models') simultaneously.

From such work it can be argued that the job of school science lessons about energy is not to provide pupils with only a single model of energy. Rather, we should aim to provide pupils with a variety of models that can be used appropriately in different contexts. Pupils should be helped to develop a plurality of intellectual spaces which they can inhabit as occasion requires. We all know the stereotype of the scientist who can only see a rainbow in terms to do with the reflection and refraction of light. Such a knowledge is incomplete. A fuller understanding of rainbows in the culture I inhabit comes with seeing Constable's watercolours, reading the poems of Wordsworth and knowing about the story of Noah's flood.

Finally, science education has the potential to serve as a platform for resistance, a notion just beginning to be explored in some science education writing (see Rodriguez, 1998) though well established in anti-racist education circles (e.g. Ahmed, Gulam and Hapeshi, 1998). For example, in a paper about teaching science to homeless children in an urban setting in the USA, Barton writes about 13 year-old Gilma. Gilma took the lead in a project, developed by the children themselves, to study pollution in their local community. Barton concluded that the main reason for Gilma's enthusiastic participation in this project in her community was "to figure out how to make it better for herself, her friends, and her family" (Barton, 1998: 385).

Why do science teachers need to take account of pupil diversity and how can they do so?

As every teacher knows, pupils differ in all sorts of ways. They arrive at school with different ways in which they prefer to learn and learn best; they arrive knowing different amounts as a result of their lives to date; and they arrive expecting to learn different amounts that day (Reiss, 1998).

What is a teacher to do faced with this diversity? To what extent are different curricula, resources and teaching approaches needed for different categories of pupils? Should, for example, the same science resources be provided for a pupil with a physical disability (such as severe sight impairment) and a pupil without such a disability? Of course not. But should both pupils receive exactly the same science curriculum? The question is a harder one. And what of girls and boys? Should they receive identical teaching approaches? Some people argue 'No'; others 'Yes' (Reiss, in press).

A related question is to do with the image that we give pupils about science. Do we still present some pupils with an understanding of science that makes them feel it is not for them?

Over the last twenty years or so, issues to do with equality in science education have, encouragingly, been taken on board to an increasing extent by professional associations, textbook authors, publishers, Examination Boards, individual teachers and other science education professionals (Thorp, Deshpande and Edwards, 1994; Cobern, 1996; Guzzetti and Williams, 1996). No longer is it implicitly assumed, for instance, that physics is largely an activity undertaken predominantly by white middle class men interested only in car acceleration and the motion of cricket balls. More generally, a greater number of teachers realise that the content of what they teach and the way they teach can turn pupils onto science or off it.

However, despite such improvements, much remains to be done. Though underresearched, differences in educational attainments in science and other subjects are very strongly related to class and economic position (Croxford, 1997; Robinson and White, 1997; Strand, 1999). In the UK, certain ethnic minority pupils, notably African Caribbean, Pakistani and Bangladeshi pupils, continue to underperform relative to other pupils in many LEAs, whereas in other LEAs these patterns are reversed (Gillborn and Gipps, 1996). While gender inequalities in the UK are considerably less than in many other countries (Harding and McGregor, 1995), girls continue to be several time less likely than boys to continue with the physical sciences once they have the option, while boys are more likely than girls to leave school with no qualifications.

Should questions to do with scientific origins be introduced in science lessons and if so, how?

Should questions to do with scientific origins - of the Universe, of life and of the human species - be introduced in science lessons? This issue has, to date, been less controversial in UK schools than in the USA. However, it is possible this could change and even if it doesn't there are good pedagogical and pastoral reasons for teachers of science thinking carefully about how to deal with the issue, especially given today's multifaith society.

There are very strong arguments for teaching in science lessons about origins. Accounts of the origin of the Universe, of life and of the human species lie at the core of cosmology and biology. However, such topics need to be handled differently to, say, teaching about equations of motion or chemical bonds for two main reasons. First, the evidence in favour of the currently accepted scientific theories about origins is less strong than the evidence in favour of many other aspects of science. This means that teachers need to ensure that they don't give the impression that currently accepted scientific views about the origins of the Universe and of life on Earth are 'proved'. Indeed, introduced carefully, teaching about origins and evolution can be a valuable way into teaching about aspects of the nature of science, for example the provisional, even tentative, nature of some scientific knowledge.

The second reason for handling topics about origins carefully in science lessons is that for a number of pupils, the issue will be of great personal significance for them. There are many science teachers for whom the notion that the Earth is only a few thousand years old and the direct result of a miraculous creation is difficult to imagine, even bizarre. Yet many pupils either hold such beliefs or come from homes where family members hold such beliefs as core aspects of their being. For such pupils, attempts in science lessons to disprove their beliefs may be personally threatening (Jackson et al., 1995; Roth and Alexander, 1997). It ill behoves science teachers to trample on such personal values.

At the same time, I consider it inappropriate to deal with this issue by omitting all serious discussion of origins from the science classroom or laboratory. To do so is to lose the heart of much of science. Here, then, are some possible learning approaches (based on Reiss, 1993) when teaching about origins in science:

- Make date-lines using string to show the possible age of the Universe and timing of significant events in the history of the Earth (1 cm = 10 million years; Universe 12 000 million years old; Earth 4500 million years old; first fossil bacteria 3500 million years old, etc.).
- Collate different creation stories (some known by pupils, others by their families, extend through library search and liaison with the RE Department).
- Make simple sedimentary rocks such as mudstones and sandstones by allowing particles to settle out from a suspension and then allowing the water to evaporate.
- See the consequence of radioactive decay (e.g. radon-220) to appreciate one technique for dating rocks.
- Look at arguments by scientists (e.g. Richard Dawkins) suggesting evolution disproves the role of God in creation.
- Look at arguments by scientists and theologians (e.g. John Polkinghorne) suggesting that evolution is compatible with the role of God in creation.
- Look at the arguments of creationists who believe that the evidence in favour of evolution is poor and that the theory of evolution is unacceptable to those with religious faith.
- Model some of the action of natural selection by getting pupils to act as 'predators' feeding on green and blue pieces of string scattered on a green school playing field.
- Discuss (apparent) difficulties with the theory of evolution by natural selection. For example, how did DNA replication get going? How might eyes have evolved? Are humans really the product of blind chance?
- Make fossil casts using plaster of Paris.
- Discuss scientific arguments for the incomplete nature of the fossil record. (The chances of fossils being formed and then discovered are tiny; much important evolution may have occurred in small populations over relatively short periods of geological time.)
- Role play public reaction shortly after the publication in 1859 of Darwin's The Origin of Species.

Follow up questions

1. To what extent are different science curricula and pedagogies needed for different categories of pupils?

2. How can science teachers provide science lessons that are relevant to the here and now and enable pupils to find space and develop resistance?

3. Should science lessons consider such controversial issues as the origins of life and the evolution of humans?

Conclusion

For all that many people (though not young children) are disillusioned with science and its promises, we still live in an age where science has tremendous cultural and technological significance. Science education has the potential to aid pupils in engaging with the world of science and in understanding both its powers and its limitations.

But science is not a homogenous whole and nor are pupils. There are a diversity of sciences and pupils differ with respect to such characteristics as gender, ethnicity, class, the extent to which they may have special needs, their preferred learning styles and other aspects of their personality and home culture. What is a science teacher to do with this diversity? This chapter argues that to take account of this diversity leads to teaching that is both just and a better form of science education.

Yet there is more to science education than coping with pupil diversity and introducing pupils to the idea that science is culturally bounded. Science education can also help pupils to resist and to create space. But before pupils can do these, their teachers may need to - seeing the constraints of imposed curricula as borderlines within which meanings are to be constructed rather than as tramlines to be followed routinely.

Finally, the question of the teaching of origins - the origins of the Universe, the origins of life and the origins of human beings - in science lessons raises important issues about the nature of scientific knowledge, the pedagogy of science education and considerations such as parental rights and the relationship between home culture and culture in society more generally. A balance needs to be stuck between omitting such topics from science lessons - for fear of upsetting people or 'causing problems' - and tackling these topics in a cavalier manner which fails to understand their cultural significance.

Further reading

A number of biographies and one autobiography are included here as these can help to bring life to science and refute the idea that scientists carry out their work independent of the societies in which they live. Well worth looking out for will be Thomas W. Goodhue's yet to be published biography of Mary Anning, the great early 19th century discoverer of fossils.

Blackmore, V. and Page, A. (1989) *Evolution: The Great Debate*, Littlemore, Oxford: Lion. A balanced introduction to the controversies around the theory of evolution.
Dawkins, R. (1986) *The Blind Watchmaker*, Harlow: Longman. A beautifully written account which argues that the diversity of life with all its wonderful adaptations does not require the existence of a creator.
Desmond, A. and Moore, J. (1991/1992) *Darwin*, London: Penguin. A great biography which examines in detail the relationships between Darwin's thinking and the cultural and political events and thoughts of his time.
Feyerabend, P. (1995) *Killing Time*, Chicago: University of Chicago Press. A wonderfully written autobiography by one of the great twentieth century philosophers of science.

Feyerabend's writing makes compulsive reading for anyone interested in science education. Especially recommended if you thought philosophy was boring.
Hodson, D. (1998) *Teaching and Learning Science: Towards a Personalized Approach*, Buckingham: Open University Press. A carefully argued book which explores how the goal of critical scientific literacy can be achieved by all pupils.
Jones, A. V. (n.d.) *Science for Special Pupils: Some Guidelines for Teachers*, Nottingham: Faculty of Science, Nottingham Trent University. A book for classroom teachers on how to teach science to pupils with special needs.
Keller, E. F. (1983) *A Feeling for the Organism: The Life and Work of Barbara McClintock*, New York: W. H. Freeman. A gripping biography of a scientist whose work was sidelined for decades because it lay outside the then current paradigm.
Leavitt, J. W. (1996) *Typhoid Mary: Captive to the Public's Health*, Boston: Beacon Press. A riveting account of Mary Mallon, the woman known as 'Typhoid Mary'.
National Academy of Sciences (1998) *Teaching about Evolution and the Nature of Science*, Washington: National Academy of Sciences. A robust defence of the argument that evolution should be taught in school science lessons.
Polkinghorne, J. (1988) *Science and Creation: The Search for Understanding*, London: SPCK. One of John Polkinghorne's many books which argue that religious faith and a belief in science are fully compatible.
Poole, M. (1995) *Beliefs and Values in Science Education*, Buckingham: Open University Press. A valuable book which examines ways in which beliefs and values interact with science and science teaching.
Reiss, M. J. (1993) *Science Education for a Pluralist Society*, Buckingham: Open University Press. A book that argues that there is no such thing as 'science' but rather a collection of ethnosciences, and explores the implications of this view for science education and classroom teaching.
Sayre, A. (1975/1978) *Rosalind Franklin & DNA*, New York: W. W. Norton. A biography of the scientist who, together with Watson, Crick and Wilkins, did the work that led to the discovery of the structure of DNA. Anne Sayre wrote the book because of what she felt was the totally misleading impression of Rosalind Franklin given in Watson's highly successful book The Double Helix.
Siraj-Blatchford, J. (1996) *Learning Technology, Science and Social Justice: An Integrated Approach for 3-13 year olds*, Nottingham: Education Now. A passionately written book which shows how global perspectives and social justice can be incorporated into technology and science teaching.

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