Science education for social justice

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Not another aim for science education?

The question as to the whole purpose of school science education has been widely debated in recent years in the science education community. Increasingly it has been agreed that school science education should serve the needs of the whole school population (e.g. Millar, 1996). For this reason, scientific literacy, however this term is understood, is seen as the prime aim of science teaching (see also Layton *et al.*, 1993; Irwin & Wynne, 1996; Hodson, 1998). Generally, scientific literacy is seen as being a vehicle to help tomorrow's adults to understand scientific issues (Gräber & Bolte, 1997). In the UK, for example, it might be hoped that a good school science curriculum that took scientific literacy seriously would help pupils to understand the uncertainties around genetically modified foods, global warming and the radiation from mobile 'phones.

My contention here is that while the scientific literacy movement has much to commend it, it still offers too narrow a vision of what science education might achieve. I would like to explore what a science curriculum might be like that took as its premise the notion that science education should aim for social justice. This is not to suggest that this should be the only aim of school science; rather, that it is an aim that has been very greatly underplayed. I aim to build on the work of a number of authors including Longbottom & Butler (1999), Longbottom (1999), Rodriguez (1998) and Barton (1998, 2001), all of whom have extended the debate about the aims of school science. Situating science education within a framework of social justice brings it alongside certain other components of the curriculum. For too long the science education debate has been conducted without reference to the wider aims of schooling.

John Longbottom explores the nature of science teaching if science education is justified in terms of socio-political goals. He argues that science education should "contribute to the advancement of democracy, and so improve the quality of human existence" (Longbottom, 1999, p. 4). Alberto Rodriguez explores the potential of science education to serve as a platform for resistance – a notion only recently beginning to be explored in science education writing, though well established in, for example, anti-racist education (Ahmed *et al.,* 1998). Angie Barton, who has worked with homeless children in the USA to develop more appropriate science learning, has shown that active participation in science lessons, and real learning about science, take place when children believe that their work can effect improvements for themselves, their friends and their families.

The nature of scientific knowledge

But first I need to address the argument that scientific knowledge is value-free and that, by extension, science education should be too. This, of course, is a two-part argument. Even if it were accepted that scientific knowledge is value-free, it would not necessarily follow that science education is too, just as even if some (?all) aspects of mathematics are value-free, this does not mean that there is no such things feminist and/or antiracist mathematics education.

In fact, the issue as to the nature of scientific knowledge, including the extent to which it is or is not value-free, is still a topic of heated debate among philosophers of science and science educators (e.g. Reiss, 1993; Ogborn, 1995;

Chalmers, 1999; Donnelly, 2002). Side-stepping this particular debate, it can be asserted that, even if we accept a characterisation of science as open-minded, universalist, disinterested and communal (Merton, 1973), all scientific knowledge is formulated within particular social contexts (e.g. Fuller, 1997). At the very least this means that the topics on which scientists work – and so the subject matter of science itself – to some extent reflect the interests, motivations and aspirations both of the scientists that carry out such work and of those who fund them. There is no doubt that the majority, almost certainly the great majority, of the funding provided for scientists, both currently and for some considerable time past, has been provided with the hope/expectation that particular applied ends will be met. These might be the production of a new vaccine, the development of a new variety of crop, the synthesis of a new chemical dye, the construction of a better missile detection system, and so on.

The point is that it can be argued that values are inevitably and inexorably conflated with science in most cases. Both the scientists and those who fund them hope that production of a new vaccine will lead to more lives being saved (presumed to be a good thing), that the development of a new variety of crop will lead to increased food yields (presumed to be a good thing), that the synthesis of a new chemical dye will lead to greater cash flows, increased profits, improved customer satisfaction or increased employment (all presumed to be good things), that the construction of a better missile detection system will lead to increased military security (presumed to be a good thing) and so on. In each of these cases, the science is carried out for a purpose. Purposes can be judged normatively; that is they may be good or bad. Indeed, just beginning to spell out some of the intended or presumed goods (increased crop yields, increased military security, etc.) alerts us to the fact that perhaps there are other ways of meeting these ends or, indeed, that perhaps these ends are not unquestionably the goods that may have been assumed (Reiss, 1999).

It can further be argued that the separation of science from values in general, and ethical considerations in particular, is a relatively recent, Western and secular phenomenon (cf. Cobern, 1998; Ogunniyi *et al.*, 1995; Haidar, 1997). In particular, Islamic science has being described as a science whose processes and methodologies incorporate the spirit of Islamic values (Sardar, 1989). Early classifications of Islamic science included metaphysics, within which was knowledge of noncorporeal beings, leading finally to the knowledge of the Truth, that is, of God, one of whose names is the Truth (Nasr, 1987). To this day Islamic science 'takes upon a more holistic human-centred approach that is grounded in values that promote social justice, public welfare and responsibility towards the environment' (Loo, 1996, p. 285).

Social justice in the science classroom

I mostly wish to concentrate on how school science education might contribute to promoting justice outside of the classroom – i.e. in the wider world. But first, it is worth mentioning that 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, 2000a).

Recent years have shown a greater acknowledgement within professional associations, textbook authors, publishers, Awarding Bodies, individual teachers and other science education professionals of the diversity among pupils that exists in science lessons as in all subjects (Thorp *et al.*, 1994; Cobern, 1996; Guzzetti & Williams, 1996). No longer is it implicitly assumed, for instance, that physics is an activity undertaken predominantly by white middle class males interested chiefly 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.

What is a teacher of science to do faced with this pupil 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? Surely 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? The issue is hotly contested.

Even when answers to such questions are clear, much remains to be done. In the UK, for example, differences in educational attainments in science and other subjects are still strongly related to class and economic position (Croxford, 1997; Robinson & White, 1997; Strand, 1999) while certain pupils from certain ethnic backgrounds continue to underperform (Gillborn & Gipps, 1996). Whereas gender inequalities in the UK are considerably less than in many other countries (Harding & McGregor, 1995), girls continue to be several times 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.

Social justice beyond the classroom through science education

Despite the widespread tendency in just about all countries to keep on lengthening the period of full-time education, students in such full-time education still spend most of their hours outside of school, college or university and there comes the time eventually when most people (academics and teachers excepted) leave these formal educational institutions. How might school science lessons prepare people for social justice beyond the science classroom?

Gaell Hildebrand (2001) has argued in favour of what she terms 'critical activism' in science education. She urges that there should be both participation in science (doing science) and participation in debates about science (challenging science). I agree. It is in doing science that pupils better understand how scientific knowledge is formed. It is in enabling pupils critically to discuss scientific issues that they not only become better able to understand the scope of science but more able to appreciate its potential for good and bad.

For we live, surely, in an age when the power of science has never been more manifest. At the same time it is fortunate that, while many secondary students, and their parents before them, have unhappy memories of much of their school science education, both students and parents almost universally consider science education to be important. In the UK, for example, science is seen as a prestigious subject and valued for the understanding it offers (Osborne & Collins, 2000; Reiss, 2000b).

To illustrate more concretely what science education for social justice beyond the classroom might consists of, here are three instances:

- food – for 8 to 11 year-olds
- nuclear power – for 12 to 14 year-olds
- individual differences – for 15 to 16 year-olds.

In each case suggestions for classroom activities are given with outline teacher notes in square brackets alongside.

Food

Here are some possible classroom activities for pupils aged 8 to 11 to tackle when learning about food.

- Find out about the different ways in which different cultures preserve food (e.g. salting, drying, pickling, curing, cooking, freezing, canning, making into jam). Research jam recipes and try making jam. What happens if the jam ends up too watery or is made without adding sugar? [All cultures have ways of preserving foods. There is no universal 'best' way. Suitable ways depend on such things as climate, availability of resources and custom. Such multicultural activities should include traditional English activities – hence jam making. It isn't easy to make jam that won't go mouldy!]
- List different food eaten by pupils in the class. Find out where these foods come from (by looking at packets, asking parents, etc.) and produce a world map of where our food is grown. [Some foods are produced locally; others far away. Obtaining all our food locally has benefits in terms of reducing the cost (financial and environmental) of transport but our diets would be less diverse and food exports are important for many countries.]
- Carry out a survey to see how much of the cooking is done by different people in a family. Are all families the same? [In many cultures cooking is a gender-specific activity but the extent to which this is the case varies considerably between cultures and across the generations. Some instances of cooking – e.g. barbecues – may show gender reversal.]
- Keep food diaries to record which foods are eaten at what times of the day. [Can relate to balanced diets. Some pupils may need to be helped to avoid making culturally-specific judgements about what constitutes an inappropriate diet.]

- Make both unleavened and leavened 'breads'. Investigate factors that affect how much leavened bread rises. [A classic primary science activity that links with religious education.]
- Research what leads to famines. What caused the Irish potato famine of 1845-9? [In one sense it was the small organism *Phytophthera infestans* (rather like a fungus). Out of a population of nine million people, over a million starved to death and about 1.5 million emigrated to the USA. However, throughout these years Irish farmers continued successfully to produce cereals, cattle, pigs, eggs and butter. Enough food was produced to endure that no one in Ireland needed to starve. Farmers had to export these crops to England to get the money they needed to pay the rents they 'owed' their English landlords. Farmers who failed to export their produce were evicted from their farms, and had their cottages razed to the ground.]
- Examine the place of food in different religious festivals (e.g. Eid, the Passover, Christmas, the Chinese New Year). [Foods have both literal and symbolic worth.]
- Find out what is meant by organic food. Why do people buy it? [Foods produced without artificial fertilisers and pesticides. Reasons include fears over human health, a wish for food to be more natural and concerns over animal welfare.]

Nuclear power

Here are some possible classroom activities for pupils aged 12 to 14 to tackle when learning about nuclear power.

- Research the roles played by such scientist as Henri Becquerel, Ernest Rutherford, Marie Curie and Lise Meitner. [Lise Meitner played a crucial role in the discovery of nuclear fission but was not awarded the Nobel Prize with Otto Hahn in 1944 for this research.]

- Plot a map of the distribution of nuclear power stations around the globe and suggest reasons for the results observed. [Nuclear power stations are expensive to build and require considerable engineering expertise. In some countries public support for new nuclear power stations is lacking.]
- Plot graphs of the decrease in radioactivity in vegetation in Cumbria in the years after Chernobyl and compare the results with government predictions. [It is taking orders of magnitudes longer for the radioactive levels to return to safe levels than had been predicted. Science is not always a certain subject.]
- Explain how carbon dioxide emissions from electricity-producing stations in France fell by two-thirds from 1980 to 1987. [Expansion of the French nuclear power industry. Over two-thirds of French electricity is generated in this way, a higher percentage than in any other country.]
- Write to both pro- and anti-nuclear power organisations asking them the same specific questions, e.g. 'How safe is nuclear power?' and 'How important is nuclear power for electricity generation?'. [Helps pupils to consider the significance of sources of scientific knowledge and enables them to consider the extent to which such knowledge is value-free.]
- Examine the medical evidence for and against an increase in the incidence of leukaemia around certain nuclear power stations. [Controversial. Can help students to appreciate how difficult it may be to see if technologies are safe or not. In addition, to what should the safety of nuclear power stations be compared?]
- Design and use a questionnaire to investigate fellow pupils' knowledge of and attitudes towards nuclear power. [A good learning experience, developing and re-inforcing knowledge about nuclear power. The work on attitudes can introduce pupils in science lessons to both quantitative and qualitative approaches to the gathering and interpretation of data.]

- Role play a Cabinet meeting trying to decide whether to extend a country's nuclear power programme or to scrap it. [Role plays don't appeal to all teachers and pupils and can polarise arguments. Alternatives include discussion in small groups. Done well, though, role plays can enhance empathy and understanding of the position of others, especially if one role plays a view different from one's own. Should be followed by de-briefing.]
- Write an imaginary letter from one of the service persons or indigenous people on test islands like Bikini Atoll. [Too little writing in science is in such a genre. Also helps pupils realise that issues of sickness and death resulting from nuclear explosions aren't restricted to Japan in the Second World War. NB controversy over use of depleted uranium shells in the Gulf War.]

<u>Individual differences</u>

Here are two possible areas for students aged 15 to 16 to study, both to do with learning about individual differences between people. In each case the idea is that students would research the issue using information from books, articles and the internet, draw on their own life experiences and then be aided by their teachers in analysing and discussing the issues. One outcome might be a long (say, 1000 word) report of the sort that is currently uncommon in science education for students in this age group to produce.

- Is there a genetic basis to differences between people in their intelligence (based on Reiss, 2000c)?

  [Many people argue that the very notion of a simple measure of 'intelligence' is deeply problematic: some question the very concept of intelligence; some argue that there are intelligences rather than intelligence; some admit the existence of intelligence but maintain that the problems in measuring it are insurmountable. Then there are arguments that, while they accept the notion of simple measures of intelligence, deny the academic worth of research programmes concerned with the genetics of intelligence. Such arguments may point out the extent to which we live in an age that inappropriately reifies the gene, or assert that no methodology can untangle the relative contributions made by the genes and the environments in which each of us has lived. Then there are the arguments from history. Attempts by previous generations, and more recently, to measure intelligence have all too often led to unwarranted prejudice and discrimination against black people, women, working class people and others.

Even if one accepts that the notion of intelligence has meaning and that there may be an inherited component to it, possible reasons can be suggested for why it might be preferable for us not to know about the genetics of intelligence. Suppose, for example, the results of such research show, appear to show or are widely taken as showing that there is an inherited component to intelligence with consistent and statistically significant (even if minor) differences between the average intelligences of different racial groups. Suppose further that these racial differences correlate (at least on average) with the possession of certain alleles. Might not such knowledge lead, on the one side (those with high intelligence), to racism or greed (The 'It's not worth educating them' viewpoint) and on the other side (those with low intelligence) to people becoming disheartened, envious or bitter ('However hard I work, I'm not going to pass my exams / get a well paid job')?]

- Why do females and males differ in behaviour?

  [Students could start by looking at, for example, clothing or the way people carry objects such as books. Are there (i) absolute differences (i.e. no overlap between the behaviours of females and males); (ii) differences between the average behaviours of females and males (e.g. what percentage of each population wears trousers or carries books held across their chest?); (iii) no differences between females and males?

Students could then consider why there are or are not differences in such behaviours, looking at the importance of cultural expectations (e.g. how one is brought up by one's parents, how one's peers would react if one suddenly behaved differently).

Students could then go on to look at generalisations about males and females, for example with regard to which sex is more athletic, which more aggressive, which more caring and which more interested in sex? Are there absolute differences or are there only differences on average? Where do such differences, if they occur, come from? Are some differences biological in the narrow sense? Are others cultural? What role do genes, hormones, upbringing, the media and so on play? How much choice does each of us have as an individual about how we behave? Are we autonomous beings or the prisoners of our genes and environment?]

What would it mean for social justice to be sought through science education and should it be?

The above examples illustrate what science classrooms might perhaps look and feel like if they had the pursuit of social justice as their aim. But what, more fundamentally, would it mean for social justice to be sought through school science, and should it be?

Social justice is about the right treatment of others (what Gewirtz (1998) characterises as the relational dimension of social justice) and the fair distribution of resources or opportunities (the distributional dimension). Of course, considerable disagreement exists about what precisely counts as right treatment and a fair distribution of resources. For example, some people accept that an unequal distribution of certain resources may be fair provided certain other criteria are satisfied (e.g. the resources are purchased with money earned, inherited or obtained in some other socially sanctioned way – such as gambling in some, but not all, cultures). At the other extreme, it can be argued either that we should ensure either that all resources are distributed equally or that all people have what they need. Such distributions might be achieved through legislative coercion, social customs or altruism on the part of those who would otherwise end up with more than average.

One would not expect school science lessons to go into much depth attempting to resolve such debates among ethicists. However, these fundamental questions are perfectly accessible to even quite young children and good school science not only provides but requires opportunities for debates about such issues as the fair distribution of resources like food, clean water and energy.

Traditionally, ethical questions concerning justice have concentrated mainly upon actions that take place between people at one point in time. In recent decades, however, these considerations have widened in scope in two important ways. First, intergenerational issues are recognised as being of importance (e.g. Cooper & Palmer, 1995). Secondly, interspecific issues are now increasingly taken into account (e.g. Rachels, 1991). These issues go to the heart of 'Who is my neighbour?' (Reiss, in press).

Interspecific issues are of obvious importance when considering biotechnology and ecological questions. Put at its starkest, is it sufficient only to consider humans or do other species need also to be taken into account? Consider, for example, the use of new practices (such as the use of growth promoters or embryo transfer) to increase the productivity of farm animals. An increasing number of people feel that the effects of such new practices on the farm animals need to be considered as at least part of the ethical equation before reaching a conclusion. This is not, of course, necessarily to accept that the interests of non-humans are equal to those of humans. While some people do argue that this is the case, others accept that while non-humans have interests these are generally less morally significant than those of humans.

Accepting that interspecific issues need to be considered leads one to ask 'How?'. Need we only consider animal suffering? For example, would it be right to produce, whether by conventional breeding or modern biotechnology, a pig unable to detect pain and unresponsive to other pigs (Reiss, 2002)? Such a pig would not be able to suffer and its use might well lead to significant productivity gains: it might, for example, be possible to keep it at very high stocking densities. Someone arguing that such a course of action would be wrong would not be able to argue thus on the grounds of animal suffering. Other criteria would have to be invoked. It might be argued that such a course of action would be disrespectful to pigs or that it would involve treating them only as means to human ends and not, even to a limited extent, as ends in themselves. More generally, the whole environmental movement has broadened its focus to non-sentient organisms (e.g. plants) and to even broader considerations (e.g. ecosystems, wildernesses).

Intergenerational as well as interspecific considerations may need to be taken into account. Nowadays we are more aware of the possibility that our actions may affect not only those a long way away from us in space (e.g. acid rain produced in one country falling in another) but also those a long way away from us in time (e.g. increasing atmospheric carbon dioxide levels may alter the climate for generations to come). Human nature being what it is, it is all too easy to forget the interests of those a long way away from ourselves. Accordingly, a conscious effort needs to be made so that we think about the consequences of our actions not only for those alive today and living near us, about whom it is easiest to be most concerned.

These issues lead more generally to the question of what might actually be the aims of teaching ethics in science, for there are other valid aims in addition to striving for greater justice. Based on Davis (1999), at least four aims can be suggested (Reiss, 1999).

First, teaching ethics in science might intend to heighten the ethical *sensitivity* of participants. For example, a chemistry teacher might encourage their students to think of what happens to household cleaners when they are poured down the sink.

Secondly, teaching ethics in science might increase the ethical *knowledge* of students. The arguments in favour of this are much the same as the arguments in favour of teaching any knowledge – in part that such knowledge is intrinsically worth possessing, in part that possession of such knowledge has useful consequences. For example, appropriate teaching about the issue of rights might help students to distinguish between legal and moral rights and to understand something of the connections between rights and duties.

Thirdly, teaching ethics in science might improve the ethical *judgement* of students. As Davis, writing about students at university, puts it:

> The course might, that is, try to increase the likelihood that students who apply what they know about ethics to a decision they recognize as ethical will get the right answer. All university courses teach judgment of one sort of another. Most find that discussing how to apply general

principles helps students to apply those principles better; many also find that giving students practice in applying them helps too. Cases are an opportunity to exercise judgement. The student who has had to decide how to resolve an ethics case is better equipped to decide a case of that kind than one who has never thought about the subject. (pp. 164-5)

Fourthly, and perhaps most ambitiously, teaching ethics in science might make student *better people* in the sense of making them more virtuous or otherwise more likely to implement normatively right choices. For example, a unit on renewable and non-renewable resources might lead students to re-use and recycle materials more. There is, within the field of moral education, an enormous literature both on ways of teaching people to 'be good' and on evaluating how efficacious such attempts are (e.g. Wilson, 1990; Carr, 1991; Noddings, 1992). Here it suffices to note that while care needs to be taken to distinguish between moral education and moral indoctrination, there is considerable evidence that moral education programmes can achieve intended and appropriate results (e.g. Straughan, 1988; Bebeau *et al.*, 1999).

Conclusions

Much school science education has been narrow in its aims, all too often serving only to train those in full-time education for possible science studies at the next age level. The scientific discourse is a tremendously powerful one and pupils and students need to be helped to examine it critically. A science education that takes seriously the search for social justice as one of its aims would be a richer education and an education more likely to satisfy students interested in fairness and human concerns. It would, though, be an education that would make new demands on science teachers in terms of aims and pedagogy.

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