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Teachers' perceptions of the role of evidence in teaching controversial socio-scientific issues

Ralph Levinson*
Institute of Education, University of London, UK

Eighty-three teachers across the curriculum were interviewed to explain their views on and approaches to, the teaching of socio-scientific controversial issues to 14–19 year olds, particularly with regard to developments in biomedicine and biotechnology. This study focused on teachers' views on the nature of evidence in controversial issues and how they deployed evidence in illuminating an issue and making judgements. Three main themes emerged: the need for facts; the reliability and validity of evidence; and the contrast between facts and values. In the first theme, three 'outlier' cases suggested ambivalence about the relevance of scientific facts or knowledge for discussion of controversy. It is suggested that there needs to be more support, focus and practice in a range of contexts in the teaching of evidence in controversial socio-scientific issues and that all sources of knowledge need to be examined critically.

Keywords: *Controversy; Knowledge; Pedagogy; Socio-scientific issues*

Introduction

Opportunities for teaching and learning about controversial socio-scientific issues have expanded over recent years in England. The statutory implementation of the citizenship curriculum in 2002 includes references to 'becoming informed citizens', 'the importance of playing an active part in democratic . . . processes', to 'express, justify and defend . . . a personal opinion . . . about a topical, spiritual, moral, social or cultural issue' and to take part in 'class discussions' (DfEE/QCA, 1999, p. 185). Such excerpts presuppose discussing controversies using evidence as a basis for justifying viewpoints, and explicit guidance on how to teach controversial issues was given in the guidance document for the citizenship curriculum (Crick, 1998). Twenty First Century Science GCSE, coming on stream in summer 2006, with its emphasis on

*School of Mathematics, Science and Technology, Institute of Education, University of London, 20 Bedford Way, London WC1H 0AL, UK. Email: r.levinson@ioe.ac.uk

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contemporary science, is likely to increase the need for support for the teaching of controversial issues (Twenty First Century Science Project Team, 2003).

Teaching controversial issues is not new to schools in England. Advocates have been prominent at both primary (Carrington & Troyna, 1988) and secondary (Wellington, 1986; Wales & Clarke, 2005) phases. The humanities curriculum project had at its core the teaching of controversy (Stenhouse, 1970) and the Inner London Education Authority in the 1980s promoted and gave guidance about the teaching of controversial issues (ILEA, 1986). With the introduction of the National Curriculum in 1988, Section 29 and legislation about the teaching of contentious issues in the 1996 Education Act (HMSO, 1996), emphasis on the teaching of controversy appeared to diminish.

Although there is now a more promising political climate for teaching controversial issues the difficulties should not be underestimated. Rudduck's report on discussion of the humanities curriculum project highlighted difficulties in the classroom (Rudduck, 1979) and reports on the teaching of controversial issues reflected lack of confidence by science teachers (Levinson & Turner, 2001) and pedagogic problems (Osborne *et al.*, 2002) in tackling contentious topics. Empirical studies of students' reasoning on socio-scientific issues have also identified obstacles for secondary students, such as the problems of recognizing the nature of disagreement between experts (Kolstø, 2004), evaluating evidence (Ratcliffe, 1999; Osborne & Ratcliffe, 2002; Zeidler *et al.*, 2002) and possible lack of maturity in the necessary strategies for decision-making (Bell & Lederman, 2003).

Moreover, socio-scientific issues are problematic precisely because of their emergent nature, often involving 'frontier science' (Bauer, 1997). An overview of the issue of xenotransplantation will give some insight into the multidimensionality and complexity of socio-scientific issues. In 2002, the pharmaceutical company PPL Therapeutics announced that it had cloned pigs with knock-out genes whose hearts could be used for transplanting into humans (Dobson, 2002). The hearts of pigs are similar in size and general morphology to human hearts. PPL Therapeutics made the announcement about these developments before the work had been peer-reviewed, leading to concerns that the company was sacrificing scientific rigour for profits (Black, 2002). Accompanying this breakthrough are ethical matters associated with rights and responsibilities and the interests of parties concerned, and also religious sensitivities (Nairne, 1996). Furthermore, xenotransplantation carries with it mythic associations with hybrids and chimaeras generating the term 'Frankenscience' from protestors wary of the consequences of the new developments in biomedicine (Boyce, 1999). Even before engaging with the complexities of the science, addressing this topic in the classroom could touch upon ethics, economics, company law, politics, scientific norms and anthropology, notwithstanding the emotions generated by the discussion of this issue. This goes beyond the professional compass of any teacher, however well versed in the topic. This difficulty is further exacerbated by the varied contexts of the interrelationships between scientific and ethical knowledge (Grace & Ratcliffe, 2002) and teachers' own uncertainties around the epistemological distinctions between ethical and scientific knowledge (Ratcliffe & Grace, 2003; Bryce & Gray, 2004).

A model for teaching controversial issues

No one single definition is likely to embrace the complexity of controversy.[1] Given the relationship between citizenship and active participation in a democratic society for the citizen-in-the-making (Crick, 1998), any depiction of controversy in schools needs to take into account those mutual obligations, contracts and constraints necessary to sustain a liberal, democratic society. In the context of discussion in the classroom these conditions presuppose moral values such as respect; openness, i.e. willingness to be swayed by compelling arguments; and equality, with everyone contributing to the discussion regardless of status (Bridges, 1979). A school which promotes democratic debate, for example, through school councils and other student representative bodies, is likely to satisfy the necessary conditions for such participation to be enacted (Crick *et al.*, 2001).

Within a functioning liberal society there is deemed to be an 'overlapping consensus' (Rawls, 1999) where reasonable comprehensive doctrines are affirmed by its citizens. Incorporated within these doctrines are the complementary attributes of rationality and reasonableness. Rational agents possess those 'powers of judgement' (Rawls, 1993, p. 51) which use means designed to meet the ends they seek. But what is missing in this description of the rational agent is 'the particular form of moral sensibility that underlies the desire to engage in fair co-operation' (Rawls, 1993, p. 51). Reasonable disagreement, then, is an 'account of the sources, or causes, of disagreement between reasonable persons' (Rawls, 1993, p. 55) in which both rationality and reasonableness operate in tandem. Drawing on Rawls's account of these disagreements, and depictions of controversy from Dearden (1981) and Bridges (1986), McLaughlin (2003) has formulated nine non-exhaustive categories of reasonable disagreement, as shown in Table 1.

These nine categories represent a broad gradation in levels of disagreement from differences which can be settled by evidence to those which are between incompatible theoretical frameworks.

The advantage of this particular categorization of disagreements is that it allows the development of a pedagogy which focuses on specific areas of an issue and can therefore make the grounds of a particular disagreement explicit. In this article I will draw upon the results of a wider study with the aim of eliciting teachers' views on teaching controversial issues through their ideas on the role of evidence, that is, on the first two categories in Table 1. Evidence, which presupposes the elaboration of data and inferences drawn from them, has particular importance in the science curriculum. For example, in the 2006 science curriculum for 14–16 year olds, pupils will be taught how to collect, analyse and interpret data; to understand the limitations, validity and reliability of data; and to know the relationship between data, evidence, theories and explanations (Qualifications and Curriculum Authority, 2006).

Evidence in the context of socio-scientific issues will be different from that usually encountered in school science, whether in illustrative or investigative work (Gott & Duggan, 1995; Driver *et al.*, 1996). In most school science contexts evidence is

Table 1. Categories of disagreement

Category	*Formulation*
1	Where insufficient evidence is as yet available to settle a matter, but where such evidence could in principle be forthcoming at some point
2	Where evidence relevant to settling a matter is conflicting, complex and difficult to assess
3	Where the range of criteria relevant for judging a matter are agreed, but the relevant weight to be given to different criteria in a given decision is disputed
4	Where a range of cherished goods cannot simultaneously be realized, and where there is a lack of a clear answer about the grounds on which priorities can be set and adjustments made
5	Where the range of criteria relevant for judging a matter are broadly agreed, but there is dispute about the proper interpretation of a criterion or criteria, given the indeterminacy of many concepts
6	Where there are different kinds of normative consideration of different force on both sides of an issue, and it is hard to make an overall judgement
7	Where there is disagreement about the criteria relevant for judgement
8	Where the differing 'total experiences' of people in the course of their lives shapes their judgements in divergent ways
9	Where there is no agreement about whole frameworks of understanding relevant for judgement

Source: McLaughlin (2003).

located within well-established theoretical frameworks. For example, the gain in mass of the solid when magnesium burns in air is explained within the framework of the oxygen theory of combustion. But the interpretive tasks confronting school students in making sense of evidence, for example whether organic foods are healthier than non-organic foods, which does not fit pre-defined models, is more crucial 'because the ''solution'' is not obvious' (Gott & Duggan, 1995, p. 33); evidence is stretched beyond warrants for substantive science, for example it is deployed in weighing judgements which draw on competing interests (Ryder, 2001). The complex task of supporting the interpretation of evidence in controversial issues would need to be part of the teacher's repertoire.

Methods

This article focuses on a wide-ranging study to elicit the views of teachers of 14–19 year olds in addressing controversial issues in their classrooms, particularly relating to the role of evidence. A framework such as the one in Table 1 is by its nature idealized. While this framework has been developed from premises based on reasonable disagreements in a democratic society it has no empirical grounding. If such a framework is to form the basis for teaching socio-scientific issues then there needs to be some compass to check how amenable is the school teaching environment for its implementation, or for its broader usefulness. And if, as expected, there is no perfect match between current practice and the framework, what are the implications?

Should the framework be adapted and, if so, how? Will there be indications for a new pedagogic framework? Or is such a framework unattainable in all or certain teaching contexts? While these questions are beyond the scope of the current paper the findings are nevertheless pertinent to the overall issue.

The purpose of this section of the article is to see how closely teachers' discussions of the role of evidence in a socio-scientific issue conform to McLaughlin's categorization of evidence—categories 1 and 2—and subsequently how this categorization can be adapted to reflect practice in the classroom.

The data for this work is drawn from a larger survey (Levinson & Turner, 2001) canvassing the views of teachers across the curriculum in teaching controversial issues based on biomedicine and biotechnology such as the human genome project, cloning and genetic screening. Questionnaires were sent out to 1000 secondary schools and further education (FE) colleges across England and Wales, with one questionnaire for the head teacher and three identical questionnaires for the heads of personal, social and health education, science and humanities. Humanities teachers were studied because the humanities curricula were deemed to be less prescriptive than those of the sciences. Religious studies, for example, addresses moral and ethical dilemmas from a wide range of areas of life. In total 305 schools responded and, out of these, 83 teachers across the curriculum were interviewed in 17 different schools. These teachers were chosen because they had indicated on the returned questionnaires that they had had experiences of teaching controversial aspects of biomedicine and biotechnology. Two teachers were interviewed in one further school (W) some time after the main project, but the same interview schedule and coding sequence were used in all schools.

After asking teachers to identify a cross-section of topics in biomedicine and biotechnology, the interview schedule contained the following areas for teachers to consider. They were asked to:

- talk about how they approached the teaching of these issues;
- exemplify any controversial socio-scientific issues they had taught; and
- discuss the opportunities and impediments presented.

The purpose of this schedule was to allow teachers to talk about the teaching and learning of controversial socio-scientific issues in terms of their own approaches and the context of teaching these issues in their particular schools and subject, involving their own understandings of pedagogy. Unintentional bias was minimized using 'hierarchical focusing' (Tomlinson, 1989) in which interviews progress from open to closed framing, keeping in mind the context of the interviewee's construals. Elaboration is sought in terms of the interviewee's responses. All the interviews were fully transcribed and thematically coded (Cohen & Manion, 1994). After reading the transcriptions a second time, using notes to identify criteria to include or exclude certain statements within categories, a protocol was written for a researcher, not involved in the original coding, to code transcripts. After reading through the protocol together a transcript was coded and any differences in interpretation

discussed. The protocol was slightly amended and a second transcript coded. This produced closer agreement, and after coding another three transcripts there was 85–90% agreement. Slight amendments were made to the protocol and the second researcher coded another ten transcripts completely separately. There was at least 85% agreement in the coding sequences.

The framing of the topic/question was left open in order to allow teachers to construct their own view of 'controversy'. All these views incorporate some notion of multiple points of view, difference and disagreement but to differing extents. The purpose of the analysis was to assess how different aspects of the framework formed part of teachers' accounts.

Teachers' discussions of evidence

A total of 51 teachers made multifarious references to evidence. For example, in one part of an interview a teacher refers to the need for facts if one is to have an opinion, and in another part discusses the problem of reliability of evidence. Teachers might also refer to two or more aspects of evidence within the same statement and these would be coded separately. For example, the statement 'It's difficult for teachers to use newspapers because they need facts not someone's opinion' would be coded under 'need for facts', 'constraints on evidence (media)' and also 'fact/opinion'. A statement can also contain two themes, for example, 'Teachers need authoritative facts' can be subsumed under 'Need of teachers for facts' and 'Constraints on evidence'. Hence there are many more statements connected with evidence than the number of teachers who made the statements.

Three main themes emerged within the category of evidence, which will be explored in what follows. These are:

- need of teachers and pupils for facts/knowledge/data/evidence/information/science (34 teachers);
- reliability and validity of evidence (30 teachers);
- distinctions between facts and opinion/value/ethics (23 teachers).

The most prominent explication of evidence in teaching in terms of number of teachers and numbers of statements is the need for information mainly for teachers, and to a lesser degree for students, to bolster the teaching of controversial issues. In this theme the terms, 'facts', 'knowledge', 'data', 'evidence', 'information', 'science' have similar meanings in the contexts of teachers' statements.

Statements referring to need for information/facts/knowledge/data for teachers could themselves be subdivided into three distinct coding schemes:

1. Statements which do not include any logical indicator to warrant, support, justify or expand the statement. These statements are: an undifferentiated need for facts; the need for: correct facts, contemporary facts, accessible facts, authoritative facts, facts at the right level of cognitive demand and types of facts (e.g. big picture

rather than detailed). An example of this kind of statement is: 'The only problem I have is that I feel you have to be very sure of your facts when you're talking about these issues and that the students can discuss things' (School B, Biology teacher).

2. Sentences or longer statements which contain explicit or implied logical indicators dealing with purposes—justifying why the facts or information or science knowledge are needed. These can be further subdivided into: facts or knowledge of science needed to support the teaching of ethics; facts needed to deal with socio-scientific issues; facts to check or counter opinion (this section overlaps to some extent with the fact/opinion theme); facts for teachers to help clarify student misconceptions; facts to help students make judgements; facts to heighten reality; facts to inform the making of decisions; facts for students to develop broad reasoning skills as a means for debate and argument. An example is: 'Teachers who are more confident about teaching the science will be more confident about teaching the ethics' (School I/Biology teacher).
3. Sentences or longer statements about the usefulness of facts. These statements were conspicuous as instances of deviant case analysis in which teachers at some point in their narrative questioned the need for scientifically based facts. Their views are important for the study as a whole because they draw attention to the problem of use of substantive scientific knowledge in addressing controversial issues. These are discussed in greater depth below.

Need for information

With the exceptions discussed below, teachers rarely expanded on how facts or content knowledge could be used for purposes such as ethical decision-making or countering opinions. This reflects teachers' priorities with the day-to-day function of teaching over reflection about the nature of evidence within controversial issues. These findings are consistent with teachers' consideration of evidence in the Evidence-based Practice in Science Education (EPSE) case-studies 'when discussing the teaching of a controversial issue in science . . . where they perceive their primary function as ''dispensers of knowledge'' providing pupils with factual information' (Bartholomew *et al.*, 2002, p. 17).

The need for scientific knowledge of some kind for all people to help in decision-making and to sustain democracy has been prominent in scientific literacy discourse. Statements emanating from policy or scholars link evidence in some form to decision-making. Hence the need for 'a healthy and vibrant democracy . . . [which] can engage critically with issues and arguments which involve scientific knowledge' (Millar & Osborne, 1998, p. 2004). Hurd's list of attributes for a scientifically literate person includes the use of 'science knowledge where appropriate in making life and social decisions, forming judgements, resolving problems, and taking action' (Hurd, 1998, p. 413). For Fourez, people could be considered scientifically and technologically literate when they possess the proper knowledge and skills to have a 'certain degree of control and responsibility in dealing with specific (technical but also emotional, social, ethical and cultural) problems' (Fourez, 1997, p. 51).

However, there is no necessarily straightforward relationship between science knowledge and understanding controversy. Debate about the problematic role of science in the curriculum has stemmed from its perceived authoritarian role in society (Ravetz, 2002), the certainty that scientific evidence is deemed to provide, the privileged status of science as a subject in the school curriculum (Bernstein, 1977; Koulaidis & Tsatsaroni, 1996) and the logico-positivist stance of science teachers (van Aalsvoort, 2004). Scientific knowledge, therefore, carries with it a received credibility and authority although contemporary scientific evidence most closely linked to socio-scientific issues is tentative, uncertain, ambivalent, contentious, subject to multiple interpretations (Bauer, 1997) and distinguished by different relationships to theory depending on context (Brickhouse *et al.*, 2000).

Ambivalent approaches to the use of knowledge

Teachers' requirements for information and facts to support teaching of socio-scientific issues contrasted with statements from three teachers which stood out as discrepant in relation to the coded themes. In *deviant case analysis* (Silverman, 2005) examination of outliers or statements which 'go against the grain' give insight into the ways in which teachers draw on data, facts or information in discussing a socio-scientific issue. These 'outlier' statements came from three teachers—a sociologist and two historians (A/Soc; T/Hist; O/Hist).[2]

While the three teachers offer arguments which question the need for substantive science knowledge, throughout these interviews there is an underlying ambivalence in their narratives. The sociologist (school A) wants 'an information pack that has all the data' on an issue such as 'the current debate about cloning' and adds 'I don't have to discuss the science issues with any real knowledge'. He is keenly aware of his own lack of knowledge of related science—'It's actually to do with my knowledge base . . . my only resource at the moment would of course be the press or media . . . I'm not a scientist so I couldn't begin to teach this'. Reflecting further on how he might approach the topic he elaborates on how his teaching would appear in his own subject area: 'In the sociology department what I would be looking at [are] the whole notions of power and power base and the role of government', and a sentence later he repeats this in detailing 'my teaching, the way it would come out would be the notion of control, power and the decision-making in our society and relationships between this and the media and democracy and so on'. Later in the interview, when asked about resources, he returns to the need for knowledge acquisition. When the teacher explains the way he would approach a topic in terms of classroom teaching experience as a sociology teacher the account excludes the need for science content knowledge. When discussing the teaching in a general sense he comes back to the need for science content knowledge.

The history teacher (school O) finds that the purpose of 'facts' in a discussion on moral issues is problematic.

> I am not saying that we shouldn't have the facts there, but if we start doing the facts, in terms of any detail, then it is easy to get away from what we are doing and end up sort of

> teaching the science rather than . . . I'm not awfully happy with the answer because it sounds as if I'm saying . . . we want the judgement without the facts being there which is not what I mean obviously, but what I'm saying is that it's the focus we are concentrating on is on the moral aspect of it.

The interviewer then asks if the teacher means that the science facts might get in the way of focusing on the moral side of things. At this point, after some initial hesitation, the teacher explains.

> I don't think from a humanities point of view or from a history point of view being provided with the scientific explanation . . . would necessarily help . . . what I perceive my job to be is to, say, look at the moral issues behind the holocaust. The chemical composition of Zyklon B makes no difference whatsoever. That's the sort of thing—I know it's not explained well—but that's the sort of thing I am looking at and again it's, yes, if you talk about Hitler's policy of eugenics I don't need necessarily a full genetic breakdown to be able to explain what we are looking at.

A few sentences later, however, when discussing resources, there is still a sense that the scientific facts cannot be fully dispensed with:

> If there are scientific facts I would want them simple enough so that even I could understand it.

A similar ambivalence emerges from the history teacher in school T. Maintaining that 'facts guide decision-making' there is also 'no real need to have an in-depth science knowledge for issues in the context of history'.

These are the only teachers who query the need for scientific facts. They feel there is a need for them, even though they cannot find a reason for facts when recounting how they would teach socio-scientific issues in the context of their own subject, or when analysing a particular moral quandary. When they give an example of the way they would approach an issue in their own subject area the science facts are excluded. Their accounts relay an uneasiness about the need for scientific facts although the need for evidence more generally is not questioned. This need for facts might be different for science teachers, but no science teachers who were interviewed explicated how facts or science knowledge would be used when teaching socio-scientific issues.

Use of science knowledge

Given the emphasis on information and evidence in the curricula and literature, teachers' requests for facts, and uncertainty around the role of science knowledge when engaging with socio-scientific issues, questions arise about the understandings of deployment of evidence in socio-scientific issues. Thomas has argued that in public policy issues such as the concerns that arose over GM foods and BSE the complexity of the science alone is likely to be too great for pupils to handle in the classroom (Thomas, 2000). Analysing case-studies of lay people's interactions with science Ryder (2001) found that there are only a limited number of contexts in which

individuals can draw on knowledge available in the school curriculum. Where understandings were significant for individuals in terms of their own or their community's lives, the knowledge required was either beyond the scope of compulsory school science, the knowledge to answer specific questions is simply unavailable, or the context of the relevant subject matter conflicts, or is at least inconsistent, with the science on the school curriculum.

Even where relevant knowledge can be drawn from the school science curriculum it does not follow that the science learned in school can be transferred unproblematically to a context in which it appears to be relevant. Socially situated knowledge is mediated by factors which transform the way in which the knowledge is used (Layton *et al.*, 1993; Irwin *et al.*, 1996; Aikenhead, 2004). This does not mean that canonical knowledge is unimportant in terms of personal or social decision-making but that it is one component of a process of transformation.

Constraints on evidence

The second theme is related to the first in that just over a third of the teachers interviewed recognized the importance of evidence but were also aware of constraints. While none of the teachers broached the relationship between evidence and theory they identified ways in which evidence was generated, validated and evaluated. The statements fell into the following coding schemes:

i. statements about the reliability and validity of evidence which drew on specific contexts (understanding the difference between tests and double blind tests; helping pupils to assess risk);
ii. who gives the evidence (this included weight given to authority; bias; scepticism about disclosure and selectivity);
iii. conflicting evidence;
iv. uncertainty of evidence.

While there was acknowledgement of the complexity of evidence, accounts about the nature of evidence were piecemeal. Teachers identified situations in which evidence could play a role—for example, whether radiation could pose a risk in mobile phone users—but there was no explanation how this factor could be tested against any suggested models. But understandings about the validity and reliability of evidence, scepticism about the source of data, recognition that evidence can be both uncertain and conflicting even from authoritative sources are likely to underpin students' evolving grasp of the role that evidence plays in socio-scientific controversies (Tytler *et al.*, 2001).

Fact and opinion

The third theme in teachers' considerations of evidence is the contrasting of fact against opinion: the fact–opinion dichotomy. In contrasting facts with opinion,

the latter has been deemed to incorporate terms which have been counterpoised to 'facts'—'emotion', 'gut feeling', 'speculation' and 'hype'. Three related sub-themes run through statements related to fact and opinion:

1. Facts are reliable and can be trusted. They are capable of being objectively true and warranted. Opinions/values, on the other hand, are incapable of being objectively true and warranted. The distinction is between factual knowledge and non-cognitive components of the question being addressed. This distinction also applies to the difference between science and other subject areas. Examples of statements in this sub-theme are: 'Teachers should give knowledge not opinions' (S/English); 'shouldn't listen to what's in the media unless written by experts' (W/Sc); 'use videos which give facts not opinions (L/Sc)'; 'We'd (RE) be looking at the moral and ethical issues whereas they (science) might touch on it, but they'd be primarily interested in the make-up of it' (J/RE).
2. Knowledge validates opinions, e.g. 'Students need factual knowledge to help them make value judgements' (L/Sc).
3. Facts might or might not change minds, e.g. 'We need facts to combat prejudice, to know the mode of transmission of HIV to overcome prejudice' (Q/Health and Social Care).

One of the problems in assuming that factual statements can be decoupled from value statements is that claims for social views have used scientific research for their legitimation. Scientific evidence has been used to justify eugenic views which are still part of 'scientific' discourse. Stephen Jay Gould describes how, in the 1980s, the prime minister of Singapore, Lee Kuan Yew, using notions of heritability of IQ, encouraged educated people to have children while advocating measures to prevent less educated people from following the same course of action. Lee justified this policy on the basis that 'There is increasing evidence that nature, or what is inherited, is the greater determinant of a person's performance than nurture. ... The conclusions the researchers draw is that 80 per cent is nature, or inherited, and 20 per cent the differences from different environment and upbringing' (Gould, 1985, p. 324). Developments in genomics have prompted Jim Watson, one of the discoverers of the structure of DNA, to advocate the use of research in genetics to promote selection against low intelligence and for beauty. 'People say it would be terrible if we made all girls pretty. I think it would be great' (quoted in Bhattacharya, 2003). Contemporary debates about evolutionary psychology demonstrate the very distinct premises and discourses with which scientists view their work and interpret data (Rose & Rose, 2001). 'Facts' that inform socio-scientific issues can be drenched in values, and highlighting the dichotomy for students might distort their understandings of the way evidence is generated and interpreted.

Science teachers in particular referred to the untrustworthiness of the media, particularly the tabloid press. Research, however, suggests that the crucial aspect is not so much that the content of the media text is untrustworthy but the need for students to understand how science stories are constructed (Jarman &

McClune, 2003) and the skills which are needed to interpret them (Phillips & Norris, 1999).

Stradling's claim that evidence can have no effect on settling a controversial issue (1984) is consistent with research reported by Thomas (1997) in which people incorporate evidence into their world views rather than shifting their world views to accommodate the evidence. None the less it seems strange to exclude the possibility that people might change their minds when new facts become available or the context around extant facts shifts in such a way as to make them more amenable for reflection. Are there, then, conditions in which decisions might be influenced by evidence?

Re-examining the category 1 of evidence in McLaughlin's framework it is possible to see that disagreements which incorporate agreed criteria around a strong evidence base lend themselves to be settled by evidence. Such disagreements presuppose openness, impartiality and objectivity on the part of the contending parties (Bridges, 1979; Rice & Burbules, 1992). An example might be the trialling of a medicine where the data are honed to demonstrate the efficacy of the medicine with minimal risk. Criteria and standards for acceptable evidence can, in theory, be formulated which are transparent to anybody who inspects the protocol. Another example is the carrying out of a highly accurate genetic test for a condition such as Huntington's disease to decide whether the individual has the condition or not. However, such a diagnosis can only confirm that the individual has the genotype, not the time of onset of the condition.

Category 2 describes conditions where disagreements are susceptible to being settled by evidence but presupposes that contending parties share values which promote agreement if certain criteria are met. These cases reflect many socio-scientific issues in which the evidence is complex and difficult to assess. In frontier biomedical technologies such as stem cell research and gene therapy evidence of success is ambivalent at present but a time may come when the strength of the evidence approaches that in the first category. These two categories, however, posit agreement on the basis that the contending parties' difference is based on how data fit a pre-defined model or set of criteria, and that the disagreement or controversy ceases to exist once those criteria are satisfied.

Conclusions

What emerges from the research is that there are few, if any, resource materials that teachers draw on to illustrate how evidence is used when discussing controversial issues. It is difficult to see how 'informed decision-making' can be enhanced unless there are clear exemplars for teachers of what this would look like in the context of teaching about socio-scientific issues in the classroom so that the use of evidence can be modelled and demonstrated to students.

Given the complexity of the interplay of theory, evidence, values, and social and political constraints it is at least helpful that teachers can focus on particular aspects of a controversy. However, the formulations described in Table 1 categories 1 and 2

are helpful to teachers only in that they describe the social conditions of the disagreement, that there is putative agreement between parties where criteria are available for settling a matter. There are procedures which teachers would have to develop with students in diverse socio-scientific contexts, including data-gathering and data interpretation, for students to begin to understand the nature of evidence in illuminating an issue. As Tytler *et al.* (2001) advocate, students could start, for example, with simple case-studies in investigative work, in which they have to identify simple causal relationships in multivariate investigations, moving on to distinguish causal from correlational relationships and so forth. It is important that teachers model and make explicit to students terms such as causality, correlation and significance. They could also make clear those instances where evidence could potentially settle a matter, such as in category 1, where the evidence is more uncertain, as in category 2, and where evidence might have no role in illuminating an issue, as in category 9. Using newspaper advertisements, where manufacturers make certain claims, will allow students to interrogate language to determine where the evidence is tentative and open to multiple interpretations. They could then come to understand that, in cases such as global warming, or understanding the relationship between radiation from mobile phones and the incidence of brain tumours, experts work within models which are themselves contested and changing (Millar, 1997). It is clear that at least a minority of teachers in our research were aware of the concepts of reliability and validity in their teaching but that they need to work with resources which fully explicate the nature of the evidence and its limitations.

In socio-scientific issues in particular it might not be helpful to highlight the distinction between facts and values and opinions but to focus instead on examining all sources of knowledge critically. Since controversy and disagreement are value-laden it is through 'intelligent reflection' on our valuations, i.e. criticism, that we can find out which value judgements are warranted and which are not (Putnam, 2003, p. 103). In a world of increasing complexity, with disparities of power and resource combined with changing social relationships with (post-)modern institutions (Giddens, 1990; Beck, 1992) techniques of self-reflection involving an increased awareness of multiple points of view will play a crucial role (e.g. Davies & Kaufman, 2003; Colucci-Gray *et al.*, 2006). There are, thus, clear implications for teacher development programmes on these issues in all areas of the curriculum.

Notes

1. Crick's depiction of a controversy is one 'about which there is no one fixed or universally held point of view. Such issues are those which commonly divide society and for which significant groups offer conflicting explanations and solutions' (Crick, 1998, p. 56). Other attempts to define a controversial issue can be found in Stenhouse (1970); Stradling (1984); ILEA (1986); Oulton *et al.* (2004); Wales & Clarke (2005).
2. The letter before the slash refers to the school; after the slash it refers to the subject teacher's specialism.

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