Science education and democratic participation: an uneasy congruence?

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Contemporary policy statements from government and reforms to science curricula in schools emphasise the importance of educating a scientifically literate public for democratic participation in science and technology. While such an aspiration is seemingly uncontentious and appears consistent with progressive educational thinking, the reality of democratic participation is problematic. I propose four frameworks for describing democratic participation in schools. The first two – deficit and deliberative democracy – fulfil a limited role for democratic participation. ‘Science education as praxis’ and ‘science education for conflict and dissent’ present more radical programmes but reflect tensions with the dominant discourse of scientific literacy and citizenship as reflected in school curricula. To operationalise aspects of democratic participation, teachers need to make explicit the role of scientific knowledge and decision-making within each framework. While radical change is likely to meet with resistance, this process will in turn generate new discourses about the problems and opportunities of democratic participation.

Keywords: democracy; participation; science education; citizenship; scientific literacy

Introduction

In a speech at the Royal Society in 2008, Ian Pearson, UK government Minister for Science and Innovation, addressing the Science, Technology, Engineering and Mathematics (STEM) Partnership Conference, justified the STEM agenda in supporting a modern knowledge economy in these terms:

… a scientifically-literate public is, in my view, an unalloyed good. With a decent understanding of evidence and risk, people are in a better position to make informed decisions for themselves and their families. They can contribute to political and ethical debates surrounding such complex issues as GM foods, biometric data, nuclear energy and embryo research – and put appropriate pressure on people like us, which is, of course, the ultimate test of our democratic process. And where a society has the confidence to engage with new technology, it tends to drive innovation through consumer demand, rather than something imposed from above on an unsuspecting and potentially sceptical public. (http://www.dius.gov.uk/news_and_speeches/speeches/past_ministers/ian_pearson/stem)

Throughout post-industrial or late-modern societies (Giddens, 1990), the curriculum links between science and citizenship for informed decision-making have become
ever closer (Bhattachary & Sheppard, 2004; Campbell, 2002; Crick, Solomon, & Cartwright, 2001; Jarman & McClune, 2003, 2007; Jenkins, 1997; Kolstø, 2001; Millar & Osborne, 1998; National Science Education Standards, 1996; Ratcliffe & Grace, 2003; Roth & Désautels, 2004; Zealand, 1993). It is not difficult to understand the reasons behind these changes. In countries with parliamentary democracies, such as the UK, there has been evidence of a breakdown of trust between citizens and policy-makers (House of Lords, 2000; O’Neill, 2002), including, and particularly through, issues of science and technology. Distrustful publics will respond negatively to the introduction of new technologies thereby threatening the nation’s competitiveness as a knowledge economy. This has resulted in attempts either to remediate the problem through greater transparency in policy-making and/or to find new concepts of citizenship and polity.

Similar themes to the Minister for Science and Innovation’s speech appear a decade earlier in the influential Beyond 2000 report (Millar & Osborne, 1998):

For the majority of young people, the 5–16 science curriculum … must provide both a good basis for lifelong learning and a preparation for life in a modern democracy.…. Our view is that the primary and explicit aim of the 5–16 science curriculum should be to provide a course which can enhance ‘scientific literacy’. (p. 2009)

This aim can be achieved by engaging ‘critically with issues and arguments which involve scientific knowledge’ (p. 2004). And one of the core criteria in Project 2061’s Science for All Americans asks: does the content help students to ‘participate intelligently in making political decisions involving science and technology?’ (2061:AAAS, 1990, pp. xix–xx)

Policy statements for science curricula with similar aspirations to that of Beyond 2000 appear in countries as diverse as Scotland (http://www.ltscotland.org.uk/Images/sciences_experiences_outcomes_tcm4-539890.pdf), Brazil (Fundamental, 1998) for example the section on Ciências Naturais e cidadania, Palestine (Wahbeh, 2003), Portugal (Basica, 2003, p. 130) and the USA (National Committee on Science Education Standards and Assessment, 1996).

Terms such as ‘participation’, ‘citizen’ and ‘democracy’ can only be viewed as good things. It would, after all, be perverse for any policy or curriculum statement to advocate education for a non- or anti-democratic society. (Plato, who was no democrat, derided democracy as a form of government because it signified the rule, kratos, of the people, demos, hence the privileging of opinion, doxa, over knowledge, philosophia – a view occasionally iterated in contemporary extreme deficit views of science governance.) Democracy, as a concept, can be used in at least three different ways. It can be a type of behaviour, for example, where people engage in egalitarian activity and respect the rights of participants. It is this type of meaning that is drawn upon when describing a democratic classroom or school. Democracy also refers in its constitutional meaning to a set of particular institutional devices, such as voting at general elections. Or it can refer to a principle of government in which there are institutions that afford some kind of public representation (Crick, 2002). It is also used pejoratively to contrast a good system of government with a bad one. Both the American (de Tocqueville, 1864) and French revolutions (de Tocqueville, 1856) as forms of civic republics, viewed citizenship as active and participative compared with late-modern societies in which individuals have the option to take an active role in civic life or not; in fact participation is often more complex than this, with people participating in one or more issues while remaining passive or indifferent to others.
Nouns such as ‘democracy’ and ‘citizen’ are slippery, historically contingent and context-specific, particularly when combined with the umbrella term of scientific literacy (Bybee, 1997; Hurd, 1998; Laugksch, 2000). There are, for example, many different ways of describing democracy: associative, representative, deliberative, radical. The danger with such ubiquitous rhetoric is that it can come to disguise problems and contradictions which, if ignored, might lead to the persistence of anti-democratic practices and ultimately disempowerment of different constituencies of the public in decision-making on scientific and technological issues. Democratic practices in science and technology, and particularly science education, raise some difficult questions in a subject that in recent school curricula has been highly framed (Bernstein, 1977) and is perceived as detached from everyday forms of human experience. Attempts, however, to humanise science and make it more popular with young people (Cerini et al., 2003; Osborne & Collins, 2000) come up against strong epistemological objections in conflating the sociopolitical milieu in which science is done from the quality of knowledge and evidence demanded in establishing truth claims (Haack, 1997). Donnelly (2004) argues that, unlike the humanities, science is instrumental; it enables prediction and control, which go beyond any values we might attribute towards its procedures. The ‘potentialities of the material world are not to be altered by any number of social values, though of course such values may well influence which possibilities are realised’ (p. 138). Not only are the technical details of scientific and technological issues frequently at a level of complexity that would confound any layperson, but the interweaving of social, economic, political and ethical matters attendant on most contentious issues deepens the problems of what democratic participation can realistically mean (Dawson, 2000; Donnelly, 2006; Thomas, 2000).

This article will overview contemporary technoscientific questions and the tensions of science and technology’s responsiveness in the public domain. Starting from Dewey’s work, I review the possibilities for educating young people in technoscientific issues in schools and proceed to identify four different teaching and learning frameworks of education for democratic participation in technoscientific issues. Practitioners within one framework might not recognise the democratic or participative credentials of those in another framework, however that is the problematic nature of the project and one that I will try to demonstrate is defensible.

Contemporary technoscientific issues: the challenge

Developments in science and technology have brought untold benefits but also anxieties about new hazards: nuclear technologies generate environmental hazards such as radioactive waste; the mass distribution of food requires the large scale use of chemical treatments, which can have deleterious effects such as soil contamination, monoculture crops and accompanying habitat threats to both plants and human settlements (Shiva, 1993); high voltage transmission lines and base stations for mobile phones have generated public disquiet about radiation effects (Drake, 2006; Siegrist & Cvetkovich, 2000; Siegrist, Earle, Gutscher, & Keller, 2005); increased international travel and cheap air fares also come with the potential for epidemics, reflected in the contemporary global concerns about swine flu (and not long before that, SARS), as well as being implicated in the production of greenhouse gases. In genomics, the science underpinning the Human Genome Project, the opportunity to locate genes or ‘polygenes’ linked to genetic diseases, has raised anxieties about conditions
that hitherto would have been unknown. The ‘healthy’ or ‘walking well’ have now become the ‘genetically unwell’ (Bennett, 2006). These contemporary hazards are objectively no greater, and arguably far more tolerable, than those in the past (and, sadly, too often in the present in many parts of the world) such as open sewers, lack of state-funded healthcare and everyday exposure to adverse climates. In wealthier societies in the twenty-first century the vast majority of people are more affluent, healthier and longer-living than their antecedents.

Events such as BSE, Chernobyl, the fear over MMR vaccines, catastrophic scenarios over nanotechnology, genetic engineering and cloning have prompted personal anxieties and fears in the so-called ‘risk society’ (Beck, 1992), although empirical studies suggest that lay people are also sanguine about technological risks (Lupton & Tulloch, 2002). Paradoxically, advances in science and technology have also helped detect and quantify the very problems that arouse public fears, such as development of instrumentation for detecting harmful effects from ionising radiation, genetic mutations and polluting gases.

If schools are the sites in which young people are educated for and through democratic citizenship to participate in the controversies raised by technoscientific issues, then it is essential to identify the characteristics – epistemic and non-epistemic, for example, sociopolitical, ethical, emotional and dramaturgical – of those issues to gain some sense of the learning and pedagogic requirements for informed decision-making. While the above issues can be classified as ‘technoscientific’ – both in the societal sense as science that emerges from social, technological, political and economic concerns (Latour, 1987) as well as in the close epistemological relationship between science and technology (Layton, 1993; Tala, 2009) – there are also many differences between each of these issues.

The procedural and declarative scientific knowledges associated with radiation effects from mobile phones (types of radiation, uncertainties, intensity, measurement of effects, epidemiology) are quite distinct from those of genetic tests (genes, alleles, heritability) and soil contamination (porosity of soils, assessment of damage to crops); even then there is little evidence that contemporary school science can address the procedural and content knowledge required to make decisions on a range of socioscientific issues (Ryder, 2001). Even if the curriculum were to expand to cover all the necessary underlying content knowledge, it would become too unwieldy.

How groups and individuals interact with these issues will also differ. Individuals seeking to determine whether they suffer from a single gene condition such as Huntington’s disease are likely to seek help from doctors and genetic counsellors although they may well belong to larger groups of activists (Rose & Novas, 2004); nonetheless their perspective is likely to relate to themselves and their immediate kin in finding answers to the question: ‘what can be done to help me?’ Public policy issues, for example the very contemporary issue as to whether to vaccinate sections of the population for swine flu (H1N1 virus), will draw on economic, media and political considerations of cost-benefit analysis and at first might involve groupings of scientists and medical experts rather than lay members of the public. Campaigns for action on global warming are likely to involve transnational groupings and interested parties from a whole variety of backgrounds as well as local campaigners. The aims, strategies and problems will all be different. Time frames will vary: the implications for a genetic test are likely to be short-term, at least for the individual, whereas environmental controversies could well take place over generations, as evidenced by the discourse of stewardship (Waters, 2001), and effects on the planet for future
generations. Some of the issues might be centred mainly around individuals or families (caring for Down Syndrome children) (Layton, Jenkins, Macgill, & Davey, 1993), communities in the disposal of toxic waste (Irwin, Dale, & Smith, 1996) or broadly-based political movements, for example campaigning groups such as Greenpeace or AIDS activism. The distinctions between these are fluid, for example individual AIDS sufferers becoming radicalised and taking part in campaigns (Epstein, 1996). The nature of the uncertainties will differ ranging from predominantly technical fixes mainly within the domain of scientific expertise (e.g. a cure for Huntington’s, although technical fixes will be constrained by moral and economic values) to wider-ranging ethical uncertainties (e.g. embryo selection, gene therapy, species conservation issues) and the public consultations associated with them, but mainly will involve both scientific and ethical uncertainties as well as economic and cultural factors. How facts and values interact will raise many problems: the Food Standards Agency finding that organic foods are no safer or more nutritious than mass-produced foods (www.food.gov.uk/foodindustry/farmingfood/organicfood/) raises questions about the media effects in reporting the answer to a question that involves broader considerations such as soil value.

Then there is the difficulty in predicting who is likely to participate in decision-making in technoscientific issues – which constituencies of the public, which experts, whether an issue will excite general national or international public interest, whether it will meet with mass indifference and whether the involvement will be long-lasting and large-scale or short-term and local. Nelkin (1982) identifies some of the complexities of influencing policy. Influencing nuclear energy policies campaigners in the US were involved in concentrating their energies on the diverse areas of federal research policy, licensing procedures, fuel supply, waste management decisions, state regulations on utility rates, permit procedures, federal and state environmental legislation and local government land use regulations (p. 60). Educating for democratic participation begs questions as to the epistemic commonalities of these issues (Levinson, 2006; McLaughlin, 2003) and the types and structures of learning that will best enhance the participation of young people.

Public concerns parallel ambivalence towards the benefits of science and technology education among young people still at school. The Relevance of Science Education (ROSE) research demonstrates that interest and enthusiasm for science and technology-related careers in secondary-age students stands in an approximate inverse relationship to national GDPs (Schreiner & Sjøberg, 2007; Sjøberg & Schreiner, 2005). The ROSE survey and Eurobarometer surveys (European Commission, 2007) suggest that young people in industrialised countries do understand and appreciate the value of science and technology in society but how they relate to technoscience is more attuned to who they are – their identities – rather than what they want to be. Single-issue politics relating to trust and identity, environmental issues and animal rights are likely to be of greater importance than careers in science and technology or an interest in national politics (Crick, 1998).

The challenge: a Deweyan perspective

About a century ago the US philosopher and educator, John Dewey, wrote about the importance of science education in serving the common good. Dewey foregrounded the instrumental nature of science, the primacy of the methods of science over facts and that science has something to say about what we do as well as how
we do it. ‘Actively to participate in the making of knowledge is the highest prerogative of man [sic] and the only warrant of his freedom. … When our schools truly become laboratories of knowledge-making … there will no longer be the need to discuss the place of science in education’ (Dewey, 1964, p. 192). Dewey’s implicit critique of the teaching of science has recognisable contemporary overtones, but the tenor of Dewey’s pragmatism is the yoking of systematic and methodical exploration of the natural world to sociopolitical purposes. In that sense Dewey’s work provides a modern (although less convincingly late-modern) framework for citizenship science.

Laboratories of knowledge-making refers to science as a process of inquiry. There is a distinction between inquiry as a learning approach in science in which students seek solutions to open-ended investigative questions (Lin, Hong, & Cheng, 2009; Minstrell & van Zee, 2000; National Committee on Science Education Standards and Assessment, 1996) and Dewey’s sense of the term, which is social and political in nature (Rudolph, 2005). Science as inquiry rejects knowledge as authoritarian and a close-ended ‘rhetoric of conclusions’ (Schwab, 1962). Through science as inquiry, scientific findings and claims become open to public and robust scrutiny, helping to staunch unwarranted assertions, manifested as anti-scientific and populist agendas, the kinds of quack science regularly attacked by Ben Goldacre in The Guardian newspaper and elsewhere (Goldacre, 2008) or ‘dogmatists, flimflam artists, and purveyors of simple solutions to complex problems’ (2061:AAAS, 1990, p. 13). Not only is the means of inquiry open and ostensibly democratic, but the purpose of the inquiry has to serve common social needs. This has particular emphasis in education as betterment: Teachers work in an educative, rather than a science-based environment, where the moral significance of school activities can only be judged in relation to the wider social world (Webster, 2008). There is a reciprocal relationship between school and community in that learners from diverse backgrounds, such as might be found in many urban environments, find themselves in schools in a space where they can communicate and share their experiences with others, leading towards shared perceptions of values. In turn the school becomes the ‘agent for the community to make available what it or the larger society, has accomplished’ (Pring, 2007). A school that separates knowledge (Dewey preferred the verb ‘knowing’) from forms of applicability is not democratic, as in the learning of Ohm’s law without linkage to the efficacy of lighting circuits or any sense of social use.

Discussion of the ‘place of science in education’ points to the role of science in the curriculum. What is central for Dewey is the deployment of intelligent reflection, the intellectual tools of science, philosophy and the arts in trying to resolve common problems, adapt to new solutions, where ‘changing one’s values is not only a legitimate way of solving a problem, but frequently the only way of solving a problem’ (Putnam, 2002, p. 98). Participants acting openly in a disagreement about the best way to solve a problem, such as prioritising fuel-saving methods over higher initial costs, might have to reconsider their goals, assumptions and values. Facts and values not only become instruments in attaining an end, but are a means subject to change and reconsideration. Interdisciplinarity is therefore, not unproblematically (Harris & Ratcliffe, 2005), a feature of a democratic school, as is the dissolving of dichotomies such as ends-means and fact-value (Hudson, 1969; Putnam, 2002). Deploying science as a tool, among others, to achieve particular ends promotes a dialectic that generates new learning and action contexts with the critical flexibility to examine the source of value positions in these new contexts.
Deweyan pragmatism repudiates intrinsic and essentialist features of objective reality and concentrates on intersubjectivity. Intellectual inquiry is not about attaining an objective truth but achieving consensus about ends and the means to achieve those ends (Rorty, 1999). Rorty makes no distinction between natural science, philosophy and literature, or between facts and values, it is simply more difficult to attain agreement about so-called values than about the description of regular objects such as a pair of shoes. This is not pure nominalism or rampant relativism. In drawing a distinction between empirical knowledge and scientific knowledge, Dewey identifies the origins of the meaning of ‘empirical’ as gaining skills through repeated practice as contrasted with science which ‘aims to free an experience from all which is purely personal and strictly immediate; it aims to detach whatever it has in common with the subject matter of other experiences, and which, being common, may be saved for further use’ (Dewey, 1916, p. 264, italics in original).

Openness to public scrutiny and social purpose has ramifications for the functioning of technical or professional expertise and its relationship to lay needs. If school education were to foreground the social and instrumental value of science then teaching would try to demonstrate that scientific research would be held accountable to public needs, or to the needs of diverse publics, and would be driven by questions about how we want to represent ourselves as a society, as exemplified by the following quote:

A consequence of this instrumental view of knowledge would be, as one might expect, the breaking down of the myth of scientific self-determination – the central component of the pure science ideology that has come to infuse representations of science in science education policy documents and curriculum materials. (Rudolph, 2005, p. 813)

If science education is both to serve democracy and to be a source of democratic values then a picture of an interdisciplinary problem-solving curriculum reflecting wider social and global matters begins to emerge. This also incorporates intersubjective values such as openness, respect and critical acumen, which I discuss later in relation to deliberative democracy, the politics of the democratic school. The citizen uses the resources of science to try to address sociopolitical, as well as individual, issues. These resources involve negotiation with scientific expertise where scientists would have to be committed to the same enterprise, i.e. shared perception of social purpose.

From a Deweyan perspective, does science as taught and learned in schools engage with sociopolitical questions such as the need for a sustainable society, concerns for social justice and human rights, and inclusivity? Hodson (2003) has argued that those ‘without a basic understanding of the ways in which science and technology are impacted by, and impact upon, the physical and the sociopolitical environment will be effectively disempowered and susceptible to being seriously misled in exercising their rights within a democratic, technologically-dependent society’ (pp. 650–651). Among the elements of Hodson’s programme is the need to move from a capitalist-driven approach of objectifying the environment to emotional dispositions of care and sensitivity towards nature. Such moves imply radical changes in teaching and curriculum structures and a blueprint in schools that is ripe for change.

Configurations of contemporary technoscience
If school science can be a vehicle for democratic participation, what kind of science is presupposed in this bigger picture? Critiques of mainstream school science have
portrayed it as a capitalist machine for enhancing the quest for corporate profits (Bencze & Alsop, 2009), an unsatisfactory re-hashing of the grand narrative of science (Lyotard, 1984), ‘value-free’ (Millar & Osborne, 1998) and, as Jerry Ravetz explained to the House of Commons Science and Technology Committee, ‘[School] science education is one of the last surviving authoritarian social-intellectual systems in Europe’ (House of Commons Science and Technology Committee, 2002).

The moves from the school study of content-led science to Science, Technology and Society (Aikenhead, 1986; Solomon, 1994; Yager & Lutz, 1995), Science, Technology, Society and Environment education (Pedretti, 2005) and Socioscientific Issues (Zeidler, Sadler, Simmons, & Howes, 2005) are a response to recognising the social, technological and ethical aspects of contemporary science through an enhanced understanding of the nature of science (Abd-El-Khalick & Lederman, 2000). In this review I focus on one of the main purposes of the sociopolitical aspects of these reforms, namely the democratic one, that science education towards scientific literacy should provide the means for informed citizens to participate in democratic decision-making on contemporary technoscientific issues.

During a similar period to the debates about scientific literacy, a reconfiguration of knowledge-making in science in late modern society was conceptualised through terms that imply the nature of this transformation: post-academic science (Ziman, 2000), post-normal science (Funtowicz & Ravetz, 1993), mode 2 science (Gibbons et al., 1994) and the ‘triple helix’ of university, industry and government (Leydesdorff & Etzkowitz, 1998). All these terms recognise the technological, social, industrial and structural changes in terms of public policy in science. They all denote a new relationship between post-Enlightenment science and society in which technoscientific innovations now mean that society is afforded the opportunity to speak back to science (Elam & Bertilsson, 2003).

Depicting post-academic science Ziman (2000) draws a distinction between science as produced in the academe within a system of Mertonian norms, broadly prevailing through the post-WWII era until late-modernity, and post-industrial, hi- tec science. Merton generated a list of rules or norms that characterised scientific practice (Godfrey-Smith, 2003). Communalism is the open sharing of information between scientists, scientific papers are open to peer scrutiny and knowledge is publicly shared. Such openness is the antithesis of secrecy and presupposes anti-authoritarian structures, in fact the norms of communication consistent with liberal democracy.1 Universality indicates the international aspect of science – the accepted scientific model of an atom of hydrogen is the same in India, the USA and Uganda, regardless of cultural and economic differences. Disinterestedness means that scientists subject their research to the critical building of public knowledge in which their own commitments and passions must take a back seat. Power structures within the scientific community suggest that this process is not always straightforward (Collins & Pinch, 1993; Myers, 1990). For scientists to subject their research to experimental replication and peer scrutiny encompasses the norm of peer scrutiny. They are precisely the kinds of rules expected in rational professional science but they preclude the social and political context in which science is practised. Nothing is necessarily inconsistent – and somewhat ironically, given its anti-authoritarian credentials – between Mertonian norms and the practices of eugenicists, Dr. Mengele’s, experiments on prisoners in Auschwitz, the scientists in the Tuskegee project who allowed syphilis to continue among their experimental human subjects to collect their data (Gray, 2001) or through the work of the Manhattan project, which resulted in the dropping of the atomic bombs
on Hiroshima and Nagasaki (Rhodes, 1986). Values of honesty and openness are integral to the scientific process, which is descriptive, but in educational ‘counter-Deweyan’ terms can be kept separate from broader value considerations.

Academic science presupposes science starting in the laboratory and advancing according to Mertonian norms. While academic science is associated with basic science, free from public accountability in the universities, industrial scientists work under different constraints, responsive to the needs of their employers and thereby reflecting human ‘interests’ even though the ethical positions on their work might be made by their employers rather than the scientists themselves. The end of the post-war boom, the threats to welfare state provision, the oil crisis of the 1970s, and increasing globalisation together with an awareness of the need for sustainability, accelerated the merging of industrial and academic science into post-academic science. While academic science persists, contemporary technoscience is largely driven by industrial and governmental needs. Characteristics of post-academic science (Kellogg, 2006) are, first, moves towards interdisciplinary transient linking of transnational groups of scientists as well as consultants, technicians, engineers, statisticians, and lawyers, such as in the Human Genome Project, compared with development of research within stable research teams. Second, there is a greater challenge of contentious technoscientific issues from public scrutiny, in discursive sites that Nowotny, Scott and Gibbons (2001) have termed the agora, reminiscent of the debating forum in classical Athens. Academic scientific knowledge has been increasingly subject to market forces as universities collaborate with business. With high profits at stake, although knowledge is now more widely distributed through open access journals and websites, it is also subject to patent law with consequent lack of openness. Post-academic science has resulted in greater inter-disciplinary enquiry, as evidenced by new hybrid technosciences such as bioinformatics and psychopharmacology, but paradoxically has also increased specialisation with division of labour. Post-academic science is also more responsive to social need. For patient groups, such as AIDS groups and cancer groups, the global campaigns for access to medicines have resulted in cheaper generic antiretroviral drugs in sub-Saharan countries but it has also meant that curiosity-driven research without any obvious application has greater difficulty in establishing itself.

In contrast to the paradigmatic Kuhnian puzzle-solving of normal science (Kuhn, 1962), post-normal science highlights the uncertainties and multi-disciplinarity of contemporary technoscience (Funtowicz & Ravetz, 1993, 1994; Ravetz & Funtowicz, 1999). It marks a transformation from Enlightenment science – value-free, objective and impersonal – to one imbued with values, diverse subjectivities and integrating multi-party perspectives. Post-normal science does not necessarily displace ‘normal’ science but supplements it. Technologies such as genomics, robotics, artificial intelligence and nanotechnology coined GRAIN, exemplify corporate global high-stakes science, which have the potential to generate tremendous changes with hoped-for huge profits. They also come with huge risks and uncertainties, the types of hazards discussed earlier. Robotics, for example, can eliminate human labour in some jobs resulting in redundancies and transforming work patterns; GRAIN is accompanied by M&M – malevolence and muddle. Giant multi-national corporations and bureaucracies responsible for initiating multi-disciplinary innovations are not under democratic control. While the projects might well be for public benefit and assume successful system functioning, they will also contain intrinsic uncertainties, which could result in malfunctioning (Ravetz, 2005). In a technoscience like genomics, systems uncertainties are high – there is no certainty about the outcomes of gene manipulations on
a large scale and research, resource investment and interests (decision stakes) are urgent. It is an area where there are conflicts in values, for example, a utilitarian approach to genomics emphasising the benefits of increased health and less strain on health services, as against an emphasis on high regulation levels and the precautionary principle to offset potential damage. An illustration as to possible effects that could be opposite to those intended is the proliferation of marketed genetic test kits that could alert those using the kits to susceptibilities to genetic conditions, resulting in higher demands on health services rather than lower.

There are plausible responses to dealing with uncertainties. At one extreme, managers and experts might concede uncertainties but claim that scientific expertise can help to reduce them. But this response sets up expert analytic frameworks requiring ‘high entry barriers’ (Jasanoff, 2003, p. 239) for lay positions to challenge the dominant technoscientific discourse. Potentially it contributes to increased tensions between experts and non-experts (Beck, 1995). On the other hand, it might be acknowledged that such systems are uncertain and indeterminate, ignorance is built into systems development – i.e. there are things we don’t know we don’t know – and that deliberative tools of decision-making are put in place for management of risk. For the latter approach science is just one of the resources for managing uncertainties, risk is not framed in purely quantitative terms but has elements of cultural, social and psychological elements (Pidgeon, Hood, Jones, Turner, & Gibson, 1992). Dialogue and stakeholder participation are intrinsic to management of risk and scientific evidence is ‘democratised’, that is, all stakeholders are engaged. This is enabled when scientists are not simply the source of scientific knowledge but become part of the policy-making process expressing their own beliefs and values and share the same social purpose. Expertise therefore becomes a skill within public scientific debate (Collins & Evans, 2002). This can be problematic. The UK Human Fertilisation & Embryology Authority’s change in regulations to permit the use of embryos in stem cell research and open up policy debate posed a challenge to stem cell scientists resulting in attempts to preserve their cognitive authority and shift the terms of the debate from a societal issue to a technical one (Parry, 2009), thereby maintaining the high entry barrier.

What emerges from these configurations of contemporary technoscience is a need to be able to solve problems and make decisions when conclusive evidence is often unavailable, values are disputed, models are complex and conflicting, and stakes and risks are high. Some of these aspects are reflected in science courses for 14–16-year-olds such as Twenty-First Century Science (Burden, 2005; Millar, 2006) (www.ocr.org.uk/download/kd/ocr_10009_kd_1_gcse_spec.pdf) but less emphasis is placed on negotiating the social and political configurations, or the complex interplay of technical information and values, which participation in late modern technoscience would demand.

The next section covers a discussion of four different frameworks for democratic participation in technoscientific issues, reflecting science-society interactions but also incorporating these frameworks in a school context.

**Scientific knowledge and democratic participation: the deficit framework**

In the UK, government and corporate responses to public disquiet about scientific and technological developments have led to a greater emphasis on public participation in decision-making, although this has been less marked in terms of participation of
The most prominent manifestation of this policy was the Royal Society report into the Public Understanding of Science (PUS), chaired by Walter Bodmer (1985), which sought to promote understanding of science in citizens for participation in a democratic society. Reasons included were the need for economic competitiveness, enhancing the democratic process in science public policy issues so that both decision-makers and individual members of the public ‘know some of the factual background … to be able to assess the quality of the evidence being presented’ (paragraph 2.7), and can engage in personal decision-making about health, understanding of everyday technologies, and science and culture, reflected in democratic and cultural justifications for doing science (Millar, 1997). Such an approach seemed a reasonable way forward in the light of less than whole-hearted public support of science. There were a few sceptical responses (Shamos, 1995; Trachtman, 1981), which were enmeshed in the Science Wars conflagration at that time (Gross & Levitt, 1998; Ross, 1996), where realists, post-modernists, Marxists and post-Marxists were engaged in claiming territory for the epistemological status of science.

Sociopolitical modes of engagement and attitudes to decision making on techno-scientific issues can be broadly categorised as two kinds: deficit and dialogic (Miller, 2001; Wilsdon & Willis, 2004; Wynne, 1995). This categorisation conceals a fuzziness between features of the two. How these engagements function in a democratic process is important because studies of these interchanges can at the least provide empirical evidence in the contemporary justifications for the reforms on citizenship and science in schools that are currently being enacted. These categories of interactions between science and lay parties reflect different depictions of scientific literacy, which have been extensively documented (Bybee, 1997; DeBoer, 2000; Fensham, 2002; Hurd, 1998; Laugksch, 2000; Miller, 1983) but I will confine myself to considering how meanings of scientific literacy emerge from them.

The deficit mode can be characterised as the public needing to be educated to understand the opportunities and constraints of contemporary science and technology so that they might realise their benefits, do not have unrealistic expectations and generally support government and corporate funding into promoting the fruits of science and enhancing the economic base (Wynne, 1995; Yearley, 1993). Crudely, this is a cognitive ‘top-up’ approach, exemplified by the Royal Society PUS report. Within the deficit approach the public is generally construed as undifferentiated. In terms of scientific literacy to have a better knowledge and understanding of the science is to contribute more fruitfully to the democratic process resulting in enhanced trust and confidence in science policy. There is limited and qualified evidence that suggests the deficit approach is effective. For example, Aldhous et al. (cited in Irwin & Michael, 2003, p. 23) carried out research that shows that when members of the public were informed about animal experimentation there was a shift towards increased support for animal experimentation for medical purposes.

Research measuring the public’s knowledge of scientific facts such as true or false responses to science questions such as ‘antibiotics kill viruses as well as bacteria’ and ‘the Earth is nearer to the sun in winter than in summer’ was the main methodology of assessing the public’s understanding of science and their competence in making scientifically-based decisions (Miller, 1983; Thomas & Durant, 1987). These research programmes were carried out through questionnaires and surveys that bestow reliability in terms of generalising individuals’ knowledge of scientific facts but less in the way of ecological validity. What is known is how people respond to particular
questions but not how they reflexively make sense of their everyday understandings. People are viewed as cognitive containers being ‘mined’ for information (Kvale, 1996).

There are a range of motivations behind the deficit approach. Government and corporate innovations depend on public acceptance. While consultations of the public take place lending institutional credibility, the terms in which the consultations are set, for example ‘What information should be made available to the general public from the regulatory system and about advances in the biosciences?’ (Irwin & Michael, 2003) strongly indicate an agenda framed from the top down in which the problems posed are predominantly technical ones. This, then, can prompt scepticism about the public’s understanding of science (Postgate, 1995) or of young people at school (Dawson, 2000; Thomas, 2000) to make, or make sense of, technically-informed decisions. Opening up technical questions to the public through a collective bargaining process can raise levels of risk rather than lowering them when left to the objective scrutiny of the expert. Democratising the role of science in society can threaten the objective validation of scientific knowledge and result in its relativisation (Gross & Levitt, 1998).

The term ‘deficit’ appears on the surface to be undemocratic and to limit participation. It has come to have paternalistic and pejorative overtones, with a model of the learner as a cognitive container. But one of the purposes of consultation through dialogue is to increase participants’ knowledge and understanding about a particular topic (Bridges, 1979), hence at some point parties to a discussion are having a knowledge deficit made up. Dickson (2000) notes in terms of scientific communication that the deficit approach can empower those participating in deliberation by communicating accurate and robust knowledge in comprehensible terms, particularly when distorted accounts of such knowledge are immediately accessible through the new technologies, a point about media literacy made in Twenty First Century Science (Millar, 2006) and in contemporary science education research on media literacy (Hodson, 2003; Jarman & McClune, 2007; Phillips & Norris, 1999). The knowledge that is problematised in technoscientific issues is not the declarative concepts of atoms, photosynthesis and forces of school science but the frontier research of contemporary science (Bauer, 1997), which is rarely in the public domain.

Curriculum reforms (2061:AAAS, 1990) and public programmes such as the Royal Society PUS report attempted to redress the problems of lack of knowledge. Within the deficit framework, a scientifically literate person would know some science as well as something about methods and procedures, applications of science and role in society. Scientific literacy is the knowledge needed ‘to understand public issues … a mix of facts, vocabulary, concepts, history, and philosophy’ (Hazen & Trefil, 1991, p. xii). Canonical science is perceived as something beyond the cognitive apprehension of most non-scientists who need to be initiated into the basics or given a sense of ‘how the world works’ (Trefil, 1997). Basic non-specialist knowledge of science will not give school students or lay people the expertise to grapple with the technicalities of a contemporary socioscientific issue but will at least give them an awareness of what is at stake in such issues. Levitt (1999) doubts if a sufficiently high proportion of the populace could have the necessary expertise to make decisions on these issues. Shamos (1995) suggests that decision-making would involve experts working with lay people on complex decision-making processes. Teaching socioscientific issues in schools could involve scientists and teachers,
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sensitive to students’ cognitive level of development, working with students on an issue, directing students to appropriate questions to consider, but, ultimately, students would be given some insight into the complexities experts have to consider in making a decision at the interface of science and society. School resources, which reflect a deficit approach, would provide relevant knowledge to be learned prior to any meaningful discussion. A view of participation in this framework is individuals or groups having the competence to know who to ask and where to gain access to relevant knowledge for decision-making rather than having a high level of scientific knowledge.

‘The boundary between “science” and “society” is envisaged as a semi-permeable membrane, through which knowledge only flows outward …’ (Ziman, 1984, p. 4). The flow is in one direction, where science is applied in the form of technology and used by society more generally (see Figure 1).

In Figure 1, derived from Ziman’s Figure, the innermost circle represents the citadel of established scientific knowledge, the ‘hard’ part of modern physical theories, which have universal truth (Weinberg, 1998); the middle circle represents the technological sphere in which the substantive science is applied; and the outermost circle represents society generally and the myriad of ways in which the technology is deployed. The arrow signifies the unidirectional flow of knowledge from the inner citadel to the outer domains; the epistemological core, akin to academic science, remains unchanged by the social changes around it. While the controversies in the outermost circle are subject to flux, the decisions can be influenced by the application of science and the knowledge, which resides in experts.

![Figure 1. Model of interface between science, technology and society.](image-url)
Characteristics of the deficit framework

Socio-epistemic relations. Students construct their socially relevant scientific knowledge with the help of the teacher. The hierarchy is scientist – teacher – student.

Epistemology. Science is the corpus of knowledge. Nature is knowable. Where there are uncertainties and tentative knowledge this resides in expert authority. ‘Hard’ science diffuses out into applied science.

Controversy and participation in technoscience. Students and lay people are unlikely to have the requisite knowledge and understanding to engage in controversial issues. Nonetheless, as well as science content they can be taught about the methods of science and controversies both within the scientific and socioscientific domains.

Pedagogy. Authority of knowledge resides within science and the teacher as science’s representative. Knowledge needed for a controversy can be brought to the attention of students.

The citizen is thus construed as an individual who has the responsibility to be informed about developments in science and technology but to recognise that they do not have the expertise to comment on complex technical decisions. Once citizens become aware of the technical complexity there will be an enhancement of trust and confidence in expert decision-making. Ethical and political aspects and value differences have only a marginal role (see Table 1).

The dialogic and deliberative framework: interactions between experts and interested parties

The dialogic or ‘contextual’ approach constructs the public as differentiated into groups or individuals bent on solving context-related problems, both with each other and with scientific experts. Scientific knowledge is not necessarily privileged and often has to be re-worked to address problems (Layton, 1986; Layton et al., 1993). The interface between learning science in schools and technoscientific issues challenges the privileged bounded status of science in the curriculum (Bernstein, 1977; Koulaïdis & Tsatsaroni, 1996) and problematises how substantive science can be brought to bear on decision-making. The predominant mode of interaction is deliberative dialogue.

Deliberative dialogue takes place in different institutional contexts: ‘core deliberative institutions’ such as parliaments, interest groups, media and coffee shops, casual conversations between friends at school or at work – and can be of different types: structured deliberation (such as formal debates), public discussion (organised public meetings around a particular issue) and casual political talk (Searing, Solt, Johnston Conover, & Crewe, 2007). All these forms of discussion usually incorporate participation and decision-making. For example, a conversation between a patient and doctor might involve the doctor not only responding to the patient’s symptoms but also the patient’s reflections on the causes and nature of the problem and coming to a mutually agreed, i.e. consensual, diagnosis and treatment. In terms of citizen participation, I want to start to examine policy-making on a broader scale, where there are controversies around the science and decisions to be taken involving different actors and interested parties. Such events might be national consultations such as GM Nation (www.aebc.gov.uk/reports/gm_nation_report_final.pdf), citizen
### Table 1. Summary of four frameworks for democratic participation in a school context.

<table>
<thead>
<tr>
<th>Framework</th>
<th>Socioepistemic relations</th>
<th>Epistemology</th>
<th>Controversy and participation</th>
<th>Pedagogy</th>
<th>Implications for democratic participation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deficit</strong></td>
<td>Knowledge flow is from scientist-teacher-student.</td>
<td>Science is the corpus of knowledge.</td>
<td>Ability to engage is constrained by access to technical knowledge.</td>
<td>Knowledge for addressing an issue can be brought to the attention of the student.</td>
<td>There is a socioepistemic inequality between the scientist/teacher and students, which limits ability to bring about political change from below but does not preclude influential specialists making a political impact.</td>
</tr>
<tr>
<td><strong>Deliberative</strong></td>
<td>Knowledge flow is predominantly from scientist to the teacher and students, the latter two might be working in concert.</td>
<td>Science is understood to be uncertain and fallible.</td>
<td>Dialogue is open. Lay participants are informed but often lack the political means to bring about change. In schools, students might have opportunities for deliberation through groupwork and school councils but action might be constrained depending on the democratic nature of the school.</td>
<td>Emphasis on critical thinking and understanding of scientific methods and procedures.</td>
<td>Participation is real but often ineffectual in generating democratic change because participants do not have the ‘clout’ to make crucial decisions.</td>
</tr>
<tr>
<td><strong>Science education as praxis</strong></td>
<td>Knowledge is distributed and emergent.</td>
<td>Knowledge is situated. Students become inducted into communal ways of knowing through legitimate peripheral participation in particular but changing contexts.</td>
<td>All participants work with a shared sense of social purpose.</td>
<td>Knowledge is provided on a need-to-know basis. The teacher is not epistemologically privileged.</td>
<td>Active and egalitarian participation to enhance change which might assume political literacy.</td>
</tr>
</tbody>
</table>
Table 1. (Continued).

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<thead>
<tr>
<th>Framework</th>
<th>Socioepistemic relations</th>
<th>Epistemology</th>
<th>Controversy and participation</th>
<th>Pedagogy</th>
<th>Implications for democratic participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissent and conflict</td>
<td>This can be variable but is likely to have similar characteristics to science education as praxis.</td>
<td>What is known is contextualised by sociopolitical concerns.</td>
<td>Political action.</td>
<td>Knowledge provided on a need-to-know basis with an emphasis on political literacy.</td>
<td>Political understanding and action for change are foregrounded.</td>
</tr>
</tbody>
</table>
juries (Dunkerley & Glasner, 1998), consensus conferences (Joss, 1998; Joss & Durant, 1995a, 1995b) and citizen planning cells (Flynn, 2008). Citizen juries, consensus conferences and citizen planning cells all involve volunteers or randomly selected lay people deliberating on a technoscientific problem such as the application of nanotechnology or the risks from mobile phones. Citizen planning cells, which are less well known, involve 25 lay people informed by specialists working on a solution to a policy problem.

As a working definition dialogue is a reciprocal conversation between two or more people, a ‘verbal interchange of thought’ (Shorter Oxford English Dictionary). The meaning of dialogue is historically located; the origin of the word is from the Greek dialogos meaning ‘conversation’. Plato’s Socratic dialogues aim to reveal absolute and timeless truth through example and counter example in disputatious arguments (Billig, 1987; Burbules, 1993) although the modern understanding has a democratic and post-modern aspect. As a means of revealing contradictions and understandings, the Socratic method is used in schools both in teaching (Chin, 2007; DePierro & Garafalo, 2003; Dillon, 1988; Edwards & Mercer, 1987; Holme, 1992) and for parliamentary style debates. Dialogue is widely associated with progressive pedagogy in collaborative construction of new ways of knowing (Alexander, 2006; Mercer & Littleton, 2007), communicating across political and social differences (Young, 2000) and as a constituent element in deliberative democracy. A contemporary definition of dialogue from a non-policy-making perspective is:

... a process of communication in which two or more participants engage in an open exploration of issues and relationships on an equitable basis. Dialogue is the exchange of ideas, opinions, beliefs, and feelings between participants – both speakers and audience. It is listening with respect to others and being able to express one’s own views with confidence. Dialogue is not silence, chaos, or one person or faction monopolizing the session. (Gammon & Burch, 2003, p. 1)

As sites of cultural reproduction schools perform an important role in initiating and developing talk in children (Barnes, Britton, & Torbe, 1986). Ability to think is dependent on talk and dialogue; sociocultural approaches mediated by language not only are deemed to enhance thought about socioscientific issues but effectively induct young people into understanding and thinking flexibly about declarative science concepts (Mortimer & Scott, 2003), although how knowledge is constructed through dialogue is still mediated by power relationships and institutional context (Lemke, 1989). Participation within the classroom forms the democratic bridge between the private and public spheres (Dewey, 1916). The reciprocal nature of talk in the classroom in the development of children’s thinking is the basis of ‘dialogic teaching’ and the work done in the Oracy project (Alexander, 2006; Mercer, 1995; Norman, 1992), which was designed to promote speaking and listening in the classroom.

In this article, dialogue is discussed within the framework of deliberative democracy and decision-making on technoscientific issues. The reason why I focus on deliberative democracy is because it best exemplifies the possibilities of dialogue that are normatively characterised in most educational thinking (Bridges, 1979; Mercer, 1995; Zeidler, Osborne, Erduran, Simon, & Monk, 2003), curriculum reforms and debates about technoscience, which are now institutionalised in some countries, such as in consensus conferences in Denmark (Blok, 2007) and the UK (Joss & Durant, 1995b).
What is meant by deliberative democracy?

A deliberative democracy is one in which free and equal citizens supply reasons to settle compelling questions on which they have divergent views (Enslin & White, 2003; Miller, 1993). Deliberative democracy contrasts with representative democracy where individuals or groups subject their preference to the political process, usually through voting (Miller, 1993). In a representative democracy this means that powerful groups are privileged through bargaining power by bringing in a range of groups for discussion. Deliberative democracy is thereby more inclusive but also, not unproblematically, presupposes dispositions and attitudes such that all can take part as free and equal citizens, where participants are committed to rationality and impartiality.

Habermas’s theory of communicative action is perhaps the best known exposition of discourse in deliberative democracy (Dunne, 1993; Habermas, 1984). The driving purpose of communicative interaction is consensus, where reasonable people strive to reach agreement. While consensus might not be reached or even attainable it is the aim of reaching consensus that underpins dialogue among reasonable people. The truth of claims emerges from the argumentative drive towards consensus, the engagement and re-evaluation of viewpoints. Achieved consensus is the ‘foundation of a good society’ (Myerson, 1994, p. 9). Engaging in rational dialogue presupposes that people have knowledge, but argument is more about how ‘speaking and acting subjects acquire and use knowledge’ (p. 2). In acquiring information or evidence relevant to a question that opens up differences, participants will have to act reasonably and co-operatively; possession of facts does not necessarily translate into rational action. Rational people hold their views open to criticism and are prepared to justify their views (Myerson, 1994).

The drive towards consensus and the marginalisation of emotion has been criticised by Putnam and Giddens, respectively. Where Habermas conceptualises dialogic rationality as the transformation from argument to agreement, Putnam (1981) holds that differences cannot necessarily be resolved through argument. Different contexts of dialogue have different criteria of rationality so there cannot be an ideal rationality. But within the framework of communicative action there are basic virtues of conduct that participants will have to demonstrate in rational dialogue, namely that assumptions have wide appeal, the ability to withstand rational criticism and a morality that should be liveable, that is, the rational is never divorced from human experience, values of justice and consideration for others (Midgley, 2003; Putnam, 1981).

Emotion and trust are the preconditions for dialogic rationality in Giddens’ scheme: ‘sensitivity and tact … balance of openness, vulnerability’ (Giddens, 1992, p. 94) encourage dialogue. Dialogue, trust (such as that between scientists and lay people) and autonomy underpin democracy. ‘How individuals might best determine and regulate the conditions of their association is characteristic of virtually all interpretations of modern democracy’ (Myerson, 1994, p. 67).

The problem of difference and marginalisation

Inequitable distribution of power and cultural capital leads to differential access to the democratic structures that allow for the voicing of conflicting views (Apple, 1979; Ellsworth, 1989) and therefore the conditions of freedom and equality cannot be assumed. There are many forums within democratic processes that can leave groups of the population marginalised: online surveys might not be available to people with limited means – the arena of debate privileges those in power and militates against
those who cannot find the time or wherewithal to take part in debate (e.g. women who are carers at home, immigrants working long hours, people not familiar with the language of the dominant group), and groups might not be able to draw on the knowledge required to defend their rights. There are therefore inequalities in what is at stake for some putative participants in a controversy:

Those whose bread is already secured, and who derive no favours from men in power … or from the public, have nothing to fear from the open avowal of any opinions, but to be ill-thought of and ill-spoken of, and this it ought not to require a very heroic mould to enable them to bear. (Mill, 2008, p. 41)

Consider, for example, the position of a disabled person in a discussion on medical genetics to prevent future forms of a disability or a refugee in a discussion on immigration. Whether the tenor of the discussion is favourable or disadvantageous to the affected party, the point is that they have more to lose (or gain) than other discussants who have no interest position.

Overcoming systemic and structural barriers dialogue can be attained in different ways; some by change within the constraints of deliberative democracy (Young 2000) others suggest that the discourse positions available within democratic structures can not provide the necessary conditions for dialogue to take place (Ellsworth, 1989, Giroux, 1988).

Forums for citizen participation in technoscientific issues

While interactions between society and science take a range of forms, in this section I shall focus on public policy deliberative issues because these are forms of citizen participation that have been most prominently researched, are aimed at influencing or responding to policy and involve interchange between a wide range of social actors and agencies, including expert and lay bodies. They illustrate the kinds of events where the ‘informed citizen’ can influence policy-making in scientific issues and the kinds of epistemic demands made on participants. They include citizen juries, consensus conferences, focus groups, consultations and planning cells. All of these forums involve recruiting lay people who take part voluntarily. They are usually initiated by large organisations such as government departments and corporations, although universities, museums and campaign groups have also sponsored citizen participation events.

Deploying the term ‘technologies of humility’, Jasanoff (2003) argues that the purpose of participation in technoscience is ‘… to make explicit the normative that lurks within the technical; and to acknowledge from the start the need for plural viewpoints and collective learning’ (p. 240). She proposes a framework of four focal points for participative engagement: framing, vulnerability, distribution and learning.

Problems are often framed in technicist terms, obscuring important social, moral and ethical dimensions. In reviewing the dispute between Monsanto and campaigning groups, Irwin and Michael (2003b) highlight how industry tends to view problems as a matter of fact (once consumers know the benefits and ‘measurable’ risks, they will be reassured), while campaigning groups alert the dangers accompanying innovations as matters of value. For example, a national consultation instigated by the Netherlands government was framed in such a way as to suggest that GM technology would go ahead, but wanted to ascertain what safeguards needed to be in place. As a result of
the framing of this debate there were challenges from anti-GM NGOs such as Greenpeace (Hagendijk & Irwin, 2006a).

‘Vulnerability’ reflects the risk of marginalisation in deliberative processes. Susceptible populations tend to be represented statistically rather than attempting to draw on the subjective experiences that take into account a sense of place and history – narratives and testimony – of individuals within at-risk populations (Pidgeon et al., 1992). ‘Distribution’ means anticipating the impacts of innovations in as fair a way as possible. Engagement between experts, managers, stakeholders and lay citizens should start at the initial upstream stages of research and development ensuring optimisation of the impacts and distributive consequences. Jackson, Barbagallo and Haste (2005) have developed a model of public engagement in research and development of new technologies. At the initial stages where outcomes, values, risks and benefits are uncertain, small-scale deliberation between scientists and other stakeholders seems most appropriate – developing into mass communication downstream. If the discussion at the early stages was based around value rather than technical considerations, then dialogue would be deemed to be ‘very constructive’. Finally, ‘learning’ enables actors looking at a problem from different perspectives and discourses to draw on the diversity and ambiguities of their experiences in devising alternative explanations and framing different problems.

The types of forums that have been most prominent in organising citizen participation in technoscientific issues are citizen juries and consensus conferences. There are some differences between these two types of event, but both are organised along similar lines and purposes (Jackson et al., 2005), namely to:

1. open up public debate – open and transparent discussion promotes democracy: the normative argument. This occurs when science is made more accessible through communication of scientific ideas in a social, cultural, environmental and practical context;
2. enhance trust and confidence in the decision-making process: the instrumental assumption; and
3. improve the quality of decision-making: the substantive perspective.

Despite the dialogic rhetoric underpinning the framing of these purposes they have a deficit core: the agenda is one predominantly driven by knowledge producers rather than users and, frequently, attempts at dialogue take place to address the consequences of an innovation, rather than anticipating distributive solutions to a problem at the research and development phase.

To identify the role that public forums for citizen participation play in deliberative decision-making, I carried out a small review of recent literature on empirical studies of citizen participation forums on technoscientific issues. There have been a huge number of studies on these forums since the early 1990s, so I have focused on the most recent to make the review manageable and up-to-date. In a Boolean search through the Sage publications database I inputted the root terms ‘citizen$ participant$', ‘sci$’ and ‘techno$’ between the dates January 2007 to August 2009. I included only those articles that reported on empirical studies or meta-analyses of empirical studies (see Table 2). More specifically, the review was intended to illustrate how far citizen participation resulted in meaningful decision-making and how ‘[loose] institutional statements of intent with regard to … “engaging in two-way communication” must be set against actual outcomes and their wider contexts.’ (Hagendijk & Irwin, 2006b, p. 182)
<table>
<thead>
<tr>
<th>Reference</th>
<th>Topic</th>
<th>Purpose of the study</th>
<th>Organiser/s</th>
<th>Format</th>
<th>Framing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Besley et al., 2008</td>
<td>Nanotechnology</td>
<td>Dissemination of deliberation through interpersonal contacts post-engagement</td>
<td>Academic department of US university</td>
<td>Internet-based survey</td>
<td>Framing of deliberations not discussed but survey focuses on how lay participants frame technology if and when disseminating</td>
</tr>
<tr>
<td>Burri, 2009</td>
<td>Nanotechnology</td>
<td>What epistemic grounds do actors draw on in evaluating new technologies when science is unknown and/or controversial?</td>
<td>Swiss Centre for Technology Assessment</td>
<td>Series of focus groups</td>
<td>Unspecific</td>
</tr>
<tr>
<td>Chilvers, 2008</td>
<td>Environmental risk and radioactive waste</td>
<td>Perspectives of participatory appraisal experts. How they construct participation, expertise and scientific citizenship</td>
<td>University</td>
<td>Interviews</td>
<td>n/a</td>
</tr>
<tr>
<td>Dryzek et al., 2009</td>
<td>GM foods</td>
<td>Assessment of ramifications when views of mini-publics (e.g. lay members of a consensus conference) clash with those of policy makers</td>
<td>Analysis by research group of a range of forums, mainly organised by policy-makers</td>
<td>Consensus conferences</td>
<td>Variable, unspecific but likely to have been through organisers of consensus conferences</td>
</tr>
<tr>
<td>Kurath and Gisler, 2009</td>
<td>Nuclear technologies, biotechnology and nanotechnology</td>
<td>Framing of lay public versus scientific experts</td>
<td>Various: Science Centres and NGOs</td>
<td>Meta-analysis and observations of dialogic participation forums such as consensus conferences</td>
<td>Lay-expert polarities, although in nanologue project ‘science and the public framed as experts’ (p.567)</td>
</tr>
<tr>
<td>Reference</td>
<td>Knowledge selection</td>
<td>Participants</td>
<td>Stage of engagement</td>
<td>Decision-making</td>
<td>Outcomes</td>
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<tr>
<td>Besley et al., 2008</td>
<td>Driven by scientists</td>
<td>Lay people and scientists</td>
<td>Downstream</td>
<td>None</td>
<td>Positive disseminations related to quality of outcomes and presentation skills of scientists; negative comments related to utility of experience, quality of discussion and competence of experts</td>
</tr>
<tr>
<td>Burri, 2009</td>
<td>Inputs by experts and a moderator</td>
<td>Lay people contacted by random mail-out</td>
<td>Upstream</td>
<td>None</td>
<td>None specified</td>
</tr>
<tr>
<td>Chilvers, 2008</td>
<td>Mainly experts</td>
<td>Experts and members of lay public</td>
<td>Unspecified</td>
<td>Variable depending on political context</td>
<td>Diverse models of democratic deliberation</td>
</tr>
<tr>
<td>Dryzek et al., 2009</td>
<td>Provided by experts</td>
<td>Lay people and scientists</td>
<td>Downstream</td>
<td>Various: voting on areas of research but ‘impact unclear’; publication of report but no evaluation of impact; consultation but impact unclear</td>
<td>None specified</td>
</tr>
<tr>
<td>Kurath and Gisler, 2009</td>
<td>Provided by experts</td>
<td>Lay people and scientists</td>
<td>Downstream</td>
<td>None</td>
<td></td>
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<tr>
<td>Lezaun and Soneryd, 2007</td>
<td>GM Nation (GM technology) (UK) and 3G mobile phones (Sweden)</td>
<td>GM nation: Large scale public consultation; 3G: enhancing dialogue between ‘well-known actors’</td>
<td>UK government; Swedish forum</td>
<td>GM Nation – widescale meetings with public; 3G – main stakeholders (not general lay public)</td>
<td>Unspecific</td>
</tr>
<tr>
<td>Powell and Colin, 2008</td>
<td>Nanotechnology</td>
<td>Shift decision-making from top down to bottom up</td>
<td>University of Wisconsin Nanoscale Science &amp; Engineering Centre</td>
<td>Meetings</td>
<td>Unspecific</td>
</tr>
<tr>
<td>Powell and Kleinman, 2008</td>
<td>Nanotechnology</td>
<td>Lay perceptions after taking part in consensus conference</td>
<td>University of Wisconsin’s Centre on Nanoscale Science and Engineering</td>
<td>Consensus conference with lay members of public questioning experts</td>
<td>Main framing by organisers with scope for content of questions from lay participants</td>
</tr>
<tr>
<td>Schibeci and Harwood, 2007</td>
<td>Biotechnology policy – gene technology</td>
<td>How institutions that underpin biotechnology policy serve to restrict community involvement</td>
<td>Study of public hearings on biotechnology regulation and legislation (Australia)</td>
<td>Public meetings with speakers only from government and industry, no campaigners</td>
<td>Programme framed by government and industry</td>
</tr>
<tr>
<td>Scott and Du Plessis, 2008</td>
<td>Human genetic testing</td>
<td>Non-specialists and experts problem-solving in non-hierarchical way; and construction of scientific citizenship</td>
<td>New Zealand research team</td>
<td>Focus groups facilitating story telling</td>
<td>Stimulus is hypothetical stories around main theme</td>
</tr>
<tr>
<td>Reference</td>
<td>Knowledge selection</td>
<td>Participants</td>
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</tr>
<tr>
<td>Lezaun and Soneryd, 2007</td>
<td>Varied</td>
<td>GM: range of experts and lay people; 3G mainly high-level stakeholders with divergent interests</td>
<td>Downstream</td>
<td>Unspecified</td>
<td>None specified</td>
</tr>
<tr>
<td>Powell and Colin, 2008</td>
<td>Institution</td>
<td>Lay people invited through local publicity shots; scientists</td>
<td>Downstream</td>
<td>None</td>
<td>To enhance engagement ‘for meaningful societal outcomes’</td>
</tr>
<tr>
<td>Powell and Kleinman, 2008</td>
<td>Organisers</td>
<td>Professional scientists, moderators, lay members of public responding to publicity</td>
<td>Unspecific</td>
<td>Release of final report</td>
<td>Gain in feeling of efficacy from participants</td>
</tr>
<tr>
<td>Schibeci and Harwood, 2007</td>
<td>Organisers</td>
<td>Government and industry</td>
<td>Broad</td>
<td>None</td>
<td>Recommendations to enhance community involvement including broader conceptions of risk beyond H&amp;S, ensure disagreement, effective use of web to inform and development of framework for community involvement</td>
</tr>
<tr>
<td>Scott and Du Plessis, 2008</td>
<td>Cultural and local resources, knowledges drawn on through process of discussion</td>
<td>Organisers, local members of interested groups (both Maori and of European origin), campaigners, activists, members of community health groups</td>
<td>Unspecific</td>
<td>Discussions by participants on how their concerns could have an impact on public policy</td>
<td>Develop more accountable decision-making</td>
</tr>
</tbody>
</table>
Table 2. (Continued).

<table>
<thead>
<tr>
<th>Reference</th>
<th>Topic</th>
<th>Purpose of the study</th>
<th>Organiser/s</th>
<th>Format</th>
<th>Framing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Williams, 2009</td>
<td>Mobile phones, risk and health</td>
<td>Facilitation of online deliberation thereby enhancing access to young people (but not those without access to internet)</td>
<td>Social scientists</td>
<td>Online synchronous discussion forum, i.e. takes place simultaneously</td>
<td>Broad framing by social scientists</td>
</tr>
<tr>
<td>Reference</td>
<td>Knowledge selection</td>
<td>Participants</td>
<td>Stage of engagement</td>
<td>Decision-making</td>
<td>Outcomes</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>---------------------</td>
<td>-----------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Williams, 2009</td>
<td>Social scientists</td>
<td>Social scientists as moderators; lay members of public with online facilities responding to advertising</td>
<td>Downstream</td>
<td>Unspecific</td>
<td>Unspecific</td>
</tr>
</tbody>
</table>
In none of the studies (Besley, Kramer, Yao, & Tourney, 2008; Burri, 2009; Chilvers, 2008; Dryzek, Goodin, Tucker, & Reber, 2009; Kurath & Gisler, 2009; Lezaun & Soneryd, 2007; Powell & Colin, 2008; Powell & Kleinman, 2008; Schibeci & Harwood, 2007; Scott & Du Plessis, 2008; Williams, 2009) was any substantive decision-making reported. Where participants published reports or took part in voting sessions (Kurath & Gisler, 2009; Powell & Kleinman, 2008) there was no discernible impact on public policy. Where explicit framing did take place (Powell & Kleinman, 2008; Schibeci & Harwood, 2007; Williams, 2009) this was devised by organisers or experts. In only one (Scott & Du Plessis, 2008) were meetings predominantly egalitarian in terms of broad framing and knowledge selection. Decision-making in this citizen participation event in New Zealand involved a wide range of interested parties where the decision-making process was a discussion of how their concerns could have an impact on policy-making. This was the only organised series of events that incorporated all Jasanoff’s (2003) four focal points, but it is too early to predict what effect their deliberations could have on policy-making. While deliberative dialogue takes place in formulating submissions for policy, these submissions are rarely implemented and the decision for action is taken by the organisation funding the forum. If this very small selection of citizen participation events is a reflection of deliberative dialogue on technoscientific issues overall, then it is unlikely that they have any material effect on policy.

Why decision-making might be so ineffective from the point of view of lay participants can be explained to some effect by an ethnographic study (Hendricks, 2006) where stakeholders such as industrialists, scientists, campaigners and end-users participating in citizen juries gave reasons for participation or non-participation. This depended on the contexts of their interests and the particular issue being discussed. The contending parties expressed wholly instrumental reasons and none of the reasons associated with the moral purposes of democratic deliberation (Young, 2000), realisation of the common good or striving to attain consensus. Only in one case in Hendricks’ study was there any purpose that met the conditions for deliberation and that was in a citizen jury covering genetic diagnostics, where patient groups saw it as an opportunity to present their personal narratives – what genetic diagnosis means to someone living with a fatal disorder (Hendricks, 2006). Reasons from industry to participate included opportunities to improve public relations, advertise products, avoid negative publicity by not taking part and educate people with the ‘real facts’ – hence deficit. From government, one of the main reasons was to improve public trust.

Reasons not to participate were also instrumental (Hendricks, 2006). Corporate interests could find more effective routes to influence government policy because of what they saw as a lack of certainty in the outcome and a lack of trust in the forum. Although some action and campaigning groups saw the possibility that they would be acting as a ‘fig-leaf’ to make respectable the arguments from some organisations, generally action groups supported the forums. Far from being marginalised those groups who represented patient groups and poorly-funded groups welcomed the citizen forums more than industry and government. For activist groups the most opportune situations were when the dominant policy paradigms were contested and unstable (Hendricks, 2006). Although the issues were instigated by big players – government and large corporations – there was little evidence from the studies in Table 2 and in Hendricks’s research (2006) of scientists taking part in equitable dialogue in the terms proposed by the criteria for dialogue in democratic deliberation.
While citizen juries promote dialogue the balance of power resides with those who drive policy, rather than with lay publics. The former fund the events, and can choose to disengage and there is no obligation to implement decisions. The structure of citizen forums would favour those who can best present a persuasive argument to an attentive body, rather than the capacity to engage in the to and fro dynamic of dialogue.

Evans and Plows (2007) have a rather different take on citizen participation such as citizen juries in which the lack of knowledge and the political indifference of the jurors play a functionally constructive democratic role in deliberative debate. Expertise is not confined to the professional scientists but seen as a distributed property of extended engagement which covers networks of interested parties from professional scientists, through to people engaged in particular forms of employment, to campaign group activists formulating assemblages (Irwin & Michael, 2003a). So, for example, experts around the installation of a nuclear power station might include pro-nuclear power parties such as nuclear scientists, company employees, and local authority planners who see opportunities for local investment. Counter-experts might be constituted from parents aware of leukaemia clusters, anti-nuclear scientists and Green party activists. Engagement at the technical phase will not only incorporate technical experts but participants who have a deep understanding of the issues, both technical and non-technical, some professional non-scientists with research degrees in science but others with understandings through engagement and experience will ‘promote critical reflection about hidden values’ (p. 834). Rather than competing with interest groups directly influencing the decision-making process, evidence and arguments are presented to non-expert disinterested citizens deploying critical faculties with as much information as is needed to make a decision, rather like the legal jury system. The initial technical phase is therefore dominated by expert assemblages but the political phase is thrown open to those whose disinterestedness and lack of commitment becomes a virtue in the deliberative process.

Participatory events, paradoxically, reveal little about functional dialogue: the main faculties demanded for decision-making from the perspectives of interested parties are persuasiveness and an understanding of where power lies. Critical thinking skills such as the ability to detect the source of claims and how they are grounded, to evaluate evidence presented and to formulate preferences based on dispassionate judgements (Bailin & Siegel, 2003), which citizen participants might need to scrutinise interested parties, are those needed by the jurors. The most powerful parties remain on the periphery of the decision-making process but they have the power to influence their own interests and the course of decision-making by choosing whether to take part or not. Participation by the big players takes place if the question is framed in such a way where they see nothing detrimental to their interests.

The social and epistemological characteristics of citizen participation forums raise questions about appropriate types of education. Only a tiny proportion of the population are likely to take part as jurors, or disinterested parties, to any significant extent. While critical thinking skills and an aptitude to engage with new technologies might be a virtue, they are hardly likely to influence the course of policy-making, which often lies in the hands of those bodies that commission the events. The type of learning needed to make effective campaigners, whether professional scientists or not, is different from that needed to scrutinise arguments (which does not mean that experts in one domain cannot be lay participants in another). The deficit mode of communication – lay citizens being inducted into technical know-how by scientists – seems to play as prominent a role as dialogue.
Characteristics of the deliberative framework (see Table 1)

Socio-epistemic relations. ‘Jurors’ are informed of technical information by scientists and hear evidence from a range of non-professional experts from interest groups. Rhetoric, argument and testimony are the main forms of presentation. Roles are subdivided: jurors can make policy decisions as a result of internal discussion but the organising institution has no mandate to carry out policy. Effective power structures are unchanged. In a school context, teachers might have an organising role but this will depend on the democratic processes within the school.

Epistemology. Technoscience is uncertain, constrained by, and often inseparable from, value positions. Nonetheless, expert scientists are reluctant to relinquish their authority status. Understanding of knowledge claims, critical thinking skills and underpinning empathy are likely to be prerequisites. An alternative configuration is epistemic assemblages, which includes both professional scientists and technologists as well as committed non-professional experts as stakeholders.

Controversy and participation in technoscience. Juror participants are likely to be non-committed. Interested parties will be on the periphery of the deliberative process.

Pedagogy. Information about science is likely to come from expert scientist(s) rather than the teacher. Teachers are instrumental in developing understanding of scientific method and critical thinking.

Participation in knowledge production: science education as praxis

The evidence of citizen participation, even in deliberative forums in technoscientific issues, suggests that the role of lay citizens is reactive rather than proactive, that they have no role in setting the planning agenda, that there is empowerment in taking part and being heard but limited scope for decision-making.

Another picture of the process of both learning and decision-making in technoscience is depicted by Roth and Calabrese Barton (2004), which sets social justice, science for sociopolitical action (Roth & Desautels, 2004) and socially-constructed knowledge at the heart of learning. The premise behind Roth and Barton’s critique of scientific literacy is that technoscience, in the undemocratic hands of corporate business, has generated environmental degradation and social injustice: ‘Science education often is a form of indoctrination to a particular worldview so that young people do not question the very presuppositions that underlie science. Scientific literacy currently [does not] reflexively also question science and scientists’ (p. 3). Such presuppositions can be exemplified in Steven Rose’s attack on the epistemic nature of molecular biology:

From its Baconian inception, modern science has been about knowledge and power, above all the power to control and dominate nature, including human nature. (Rose, 1998)

Scientific knowledge as taught in most schools, and as critiqued in reform documents (Department of Education and Early Childhood Development, 2009; HM Treasury, 2004; Millar & Osborne, 1998; National Research Council, 1996), reinforces abstract concepts that do not reflect science and technology as experienced by most individuals
and therefore school knowledge does not transfer easily into science and technology as practised in everyday life (Ryder, 2001). One option is to dissolve the metaphorical and physical walls that separate schools from campaigns for justice in the local community, to conceive of citizen science as a way of knowing that is communal and distributed and that addresses the ‘concerns, interests and activities of citizens as they go about their everyday business’ (Jenkins, 1999). When learning, students move from the periphery of the task, i.e. what needs to be done to solve the problem, as they construct social knowledge, which is embedded within the tasks at hand (Wenger, 1998). This activity is always going to involve agents with different motivations, interests and concerns, in which science is used as a tool among others to highlight or resolve conflict and, in so doing, transform the dialectic – actions and agents in relation to those actions are changed and re-identification takes place.

Roth and Lee (2004) describe a project that reflects a reconstructed scientific literacy in which 7th grade school children take part with the community in a movement to clean up a polluted creek in their area. Finding ways to restore the creek – such as constructing riffles to allow the water to tumble and become better oxygenated – means collaborating with many different interested groups. These include environmental campaigners, local residents, farmers and scientists, all with different motivations but all with the purpose of clearing the watershed. First Nation elders recall how the creek was used before the changes to accommodate more homes and the stories that had built up over the years over its use. How the community interacts to build knowledge and achieve change is conceived through activity theory in which the unit of analysis is not individualised discrete knowledge but the activity with all its interacting constituent ontic entities: the subjects in relation to the object of the activity, the tools used to achieve outcomes, rules which mediate the relationships and the roles of participants and division of labour.

Motivation for students to take part was provided by the local community newspaper. The students already knew something about the project in their local area and many of their parents were already involved. They investigated how to improve the creek based on their own interests, often involving different kinds of specialisations and interactions, sometimes using laboratory equipment supported by professional scientists to monitor measurements such as oxygen and pH levels, representing data in ways that were most meaningful to them and contributing through seminars. Parents were involved in helping to transport children to the sites but also in eliciting and refining information by asking questions. There are no epistemic or institutional boundaries between school activities and the local community but the school students and teachers become part of the warp and weft of the communal purpose.

While the saltwater creek project represents integration of school science within a larger communal purpose, caution is needed in generalising from projects such as this one. First, students and teachers already had some knowledge of the environmental problem that faced them because of the roles their colleagues, friends and parents played within the project. But in larger, urban, more highly stratified social situations, this specific form of collaboration becomes more difficult to achieve. Second, this was a teacher-initiated rather than a student-initiated programme, although students appear to have been comfortable with the roles they chose. Third, Roth and Lee (2002) in describing the singularity of purpose in cleaning up the creek also acknowledge social tensions and lack of dialogue, particularly among First Nation people and other local residents. Despite the emerging problems the members of the ‘saltwater people’ have
not been as active as might be expected in environmentalists’ efforts to reduce contamination, preserve the watershed and to bring back trout to the creeks. One explanation given by a member of the First Nation community is that the efforts of the environmentalists are still alien to the wisdom about the habitats possessed by the indigenous peoples, that dialogue failed to take account of their views, a problem with dialogue between culturally dominant groups and First Nation peoples (Jones, 1999).

Fourth, while there was collaboration between experts and the community, such as professional scientists providing support for instrumentation, there were also conflicts between scientific experts and lay participants, often resulting in lack of consensus about meanings such as the criteria of toxicity for levels of chromium in the water supply (Roth & Lee, 2002). Nonetheless this last problem resolves itself into a dialectic between expert generalised knowledge and local lay empirical knowledge, where particularities in a problem refute expert findings. Examples of these are parents of Down Syndrome children questioning the role of knowledge of molecular biology in helping them care for their children (Layton et al., 1993) and challenges from local residents on public health grounds about contamination of local water supplies where residents working with a public health expert they employed were able, through their own epidemiological studies, to provide the evidence of the spread of childhood leukaemia and to locate the cause of the problem (Brown & Mikkelsen, 1990).

The Sci:dentities project

Another example of collaborative production of contentious scientific knowledge is an arts-organised activity, the Sci:dentities project (McNamara & Rooke, 2008), involving young transsexual and transgendered people in London. Through a series of arts workshops they explored the question ‘What is the science of sex and gender?’ The contemporary significance of this issue is reflected in the controversy over the young South African athlete, Caster Semenya. (Semenya won the women’s 800 metre event at the World Championships in 2009 in Berlin. The media and officials cast doubt on her gender status and pressure was put on her to undergo ‘gender tests’. See news.bbc.co.uk/sport1/hi/athletics/8344591.stm)

While the setting for the Sci:dentities project was not a school or a local community, the activities were organised into science and arts sessions like a school curriculum. The experiences of the narratives generated by the young trans people drew on the inadequacy of sex education lessons at school, as an example from one of the participants, indicates:

Schools don’t teach about being transgendered or transsexual. … How much happier I would have been if I could have known earlier? How much easier would it make it for so many children and young people if they could know they weren’t alone? How many lives might have been saved if only, if only, someone in authority would acknowledge the necessity for young people to know that it’s okay to be different, to be gender variant? (McNamara & Rooke, 2008, pp. 185–186)

The process of collaborating and generating narratives with other young trans people infused the participants with a strong sense of identity and in-depth knowledge about the social construction of gender and the tendency to reification of gender by the medical establishment. Question-and-answer sessions with doctors, and diaries produced by the participants, revealed gaps in perceptions. Doctors explained trans conditions as medically problematic in terms of chromosomal abnormalities and
hormonal imbalances while the young trans participants refuted the doctors’ interpretations. At the end of the project the young people produce works of art drawing on their experiences of the project and their emerging identities, producing new interpretations of the scientific basis of being trans-gendered.

Science education as praxis: distinguishing features
What are the distinguishing features of the Henderson Creek and the Sci:identities projects and to what extent do they reflect democratic participation?

Science as emergent knowledge
In the cases just described the participants have a shared aim, to solve a problem or problems that affect all participants: how to clear the creek; and how to explain identities and possibly transform identities related to trans-sexuality. Science is a tool, among others, contextualised in the problems that participants try to solve (either about the local environment or their own emerging identities) rather than decontextualised knowledge with no immediate bearing to everyday life; knowledge is therefore emergent and situated rather than discrete and generalised, as described in Figure 1. Learning is led by social needs and concerns rather than by a pre-prepared curriculum. Consciousness, and hence discourse, presupposes and is pre-figured by action and labour (Freire, 1996), hence learning is led by social needs and concerns rather than by a pre-prepared curriculum.

Knowledge as distributed
Knowledge is distributed and communal, rather than hierarchical and individualised, inviting participation in learning through a joint enterprise. There is scope for different ‘experts’ but all participants use and draw on their emergent knowledges in solving problems, which change in nature as more knowledge becomes available. Trans young people, for example, become conscious of new conflicts as their conversations with medical personnel highlight new possibilities of dialogue. Participation is not per se democratic when it might, for example, be driven by populist oppression of minority groups or the negation of the rights of others. The emphasis on participation is through collaboration, communication as in communal understanding and co-operation (Beane & Apple, 1995).

Knowledge as inter-disciplinary
The Henderson Creek project draws on the testimonies of First Nation residents, local knowledge of farmers, residents and planners and scientific knowledge of ecologists. The Sci:identities project draws on (and challenges) medical knowledge, experiences of health experts and narratives of trans participants modelling emergent ways of knowing through works of art.

Relationship between expert and lay knowledge
Scientific knowledge is deconstructed to use as a tool to challenge expert knowledge which might be seen as oppressive and unrelated to immediate concerns. Knowledge
is conceptualised as contested and a site for struggle. For example, challenges towards expert knowledge at public meetings of the Henderson Creek project, where even responses of affirmation and disagreement among the audience supply rhetorical flourishes and sustain the ongoing dialogue.

Contamination of the creek is described by one expert as an ‘aesthetic’ matter (Roth & Lee, 2002); the trans participants in sci:densties problematise the medicalisation of trans-ness. Professional expert knowledge does not have an epistemologically privileged status. It is, as Ravetz (2005) suggests, that participation becomes democratic when scientists are part of the enterprise, or within ethno epistemic assemblages (Irwin & Michael, 2003a).

**Scientific literacy**

Scientific literacy emerges as collective learning rather than knowledge within an individual and is likely to produce diverse representations of knowledge-building as opposed to scientifically accepted ones.

**Citizenship**

Young people are, and see themselves as, citizens (Alderson, 2000) whose voices are authentic and heard rather than as citizens-in-the-making or future citizens (Crick, 1998, Millar & Osborne, 1998).

**Scientific literacy**

Scientific literacy emerges as collective learning rather than knowledge within an individual and is likely to produce diverse representations of knowledge-building as opposed to scientifically accepted ones.

**Action and authenticity**

The focus is on action for change and authenticity rather than school-valued knowledge.

Prins, Bulte, Van Driel and Pilot (2008) identify features of authentic practice: a mutually understood purpose of all participants, i.e. the improvement of the watershed or the production of art which evokes meanings of what it is to be a young trans person, and using necessary knowledge to achieve that purpose. Murphy, Lunn and Jones (2006) and Hennessey and Murphy (1999) distinguish between cultural authenticity where students ‘participate in science-based discourses around social issues involving a range of communities’ (Murphy et al. 2006, p. 232), which also requires students ‘to participate in critically evaluating the knowledge claims of science’ (p. 232), and personal authenticity by perceiving what is relevant and has value and meaning in their learning. Authenticity, then, includes social and personal components.

But there is a different move in claiming authenticity for school-based science which aims to re-present activities from ‘real life’ through role play (Simonneaux, 2001) and what Buxton (2006) terms ‘contextually authentic science’. Contextually authentic science is a blend of canonical science associated with the logico-scientific rationality of the professional science community and is ‘youth-centred’, which
comprises the values and perspectives of young people in a collaborative enterprise to solve shared problems. Authentic collaborative action stems from the needs, concerns and shared values of participants using science as a means of actualising those desires. But if the use of canonical science in authentic problem-solving contexts is problematic (Layton, 1993; Levinson, Murphy, & McCormick, 1997; Ryder, 2001) then the process of re-situating canonical knowledge needs to be made explicit. It is not that canonical knowledge is necessarily redundant in solving problems of public or communal policy, but how that knowledge can be activated, for example, through experience in learning about the epistemology of science in understanding how uncertainties arise, recognising inherent variability in measurements and how sampling techniques are carried out (Ryder, 2002).

How far action can be said to reflect the volition of participant actors is a psychologically problematic area. But there does appear to be a distinction between those activities which are initiated by the agents of change and where learning is imposed from without. There is a distinction between many school-based activities where there are quite legitimate elements of contrivance, however realistically situated the activities are, and actions which are shaped by the sociopolitical context of the participants. The distinction between the school context and democratic participation becomes fuzzy or disappears where the technoscientific problems to be solved are shared by the school and community in a spirit of collaboration and co-operation (Beane & Apple, 1995; Trafford, 2008).

In citizenship participation forums, the agenda is set by agencies beyond the control of the core lay participants (Hendricks, 2006; Lezaun & Soneryd, 2007). In the science curriculum reforms the educational agenda is out of the hands of the students and therefore there is always an element of compliance.

Producing knowledge as a way of addressing shared problems starts from the point of framing the problem. New knowledge emerges as actors work collaboratively in transforming their reality and the nature of the authentic problem they are engaged in. Where knowledge is distributed in solving communally-framed problems, through inquiry deliberative dialogue becomes a resource when farmers and ecologists and school students generate knowledge in the context of to and fro questions about salmon stocks. Here each response to a question is not only an outcome but becomes integrated into the developing dynamic of the activity and becomes ‘a resource available to the community as a whole’ (Roth & Calabrese Barton, 2004, p. 45).

Canonical science becomes one resource among others in the context of solving problems where uncertainties become objects of inquiry, reflection and contestation as in the challenging of the expert on chemical contamination at the public meeting, and the challenges by young trans people on medicalising sexual identity. Since knowledge is distributed and emergent there is no necessary epistemic hierarchy; through participation in contextual and contested ways of knowing, participants become acculturated into a community of knowing (Lave & Wenger, 1991). Interdisciplinarity, co-construction of knowledge and common purpose are the significant features of these enterprises. Metaphorical walls between school and community are dissolved. In Figure 2 the communally derived problem determines what needs to be known rather than specialised knowledge applied to technoscientific change as seen in Figure 1. But solutions anticipate new problems and new ways of collaborating which influence identities and concerns. There is therefore an open dialectic based on socially transacted need compared with the deterministic configuration in Figure 1.
Characteristics of science education as praxis

Socio-epistemic relations. Knowledge is distributed and emerges through praxis. Communal purpose and activity override any distinctions in terms of ownership of knowledge. Since knowledge emerges through the framing and re-framing of contextualised problems, knowing-through-action, there is no authority but there are authoritative ways of knowing.

Epistemology. Knowledge is both situated and emergent. Through legitimate participation, participants become inducted into more sophisticated and shared techniques of problem solving. Scientific knowledge is contestable and open to participant reflexivity.

Controversy and participation in technoscience. All participants, scientists and non-scientists, subject their views to communal questioning and reflection.

Pedagogy. How canonical science is refracted and transformed through social, ethical and political concerns needs to be made explicit. Knowledge is provided on a need-to-know basis (see Table 1).

Participation through conflict and dissent: moves towards scientific citizenship
The frameworks of democratic participation I have discussed so far presuppose decision-making through existing democratic institutional structures, be they citizen...
juries, schools, local authorities or parliamentary bodies. The presumptions of democratic deliberation are that consensus about differences, what Rawls terms burdens of judgement, ‘the sources, or causes, of disagreement between reasonable persons’ (Rawls, 1993, p. 55), can be attained through rational discussion among reasonable contending parties. Young (2000) has pointed out that there is scope within deliberative structures to achieve dialogue across social difference and power and bring in marginalised parties through, for example, spaces made for counter storytelling.

But there are quite notorious examples where the forums of deliberative democracy have simply not been available to those who suffered from accidents such as the leak of methyl isocyanate from the Union Carbide plant in Bhopal in 1984, the Tuskegee syphilis scandal or the biopiracy of the Neem tree in India (Shiva, 1997). While striving to achieve justice constitutes a central theme of democratic deliberation, it does not follow that justice will be achieved when the suffering parties feel the odds are stacked against them. Dialogue is simply not seen as an option. Where reasonableness and calm are seen as the virtues in liberal formulations of deliberative dialogue, feelings of outrage and injustice can become a barrier and exclusionary. While questioning the assumptions of any topic is a constitutive part of dialogue, Hendricks’ (2006) research shows how easily those who have political hegemony can both set the terms and remove themselves should those terms not suit them. In schools, dialogue can appear as a means of co-option for some students without attending to underlying problems and issues. Dialogue is a means of questioning and resolving differences where there are nuclei of agreement and common discourses (Billig, 1991; MacIntyre, 1988) but not in encompassing radically different, incommensurate points of view, where voices go unheard because they are simply not understood or there are no normative categories, a shared historical tradition for example, for dissonant claims.

Identifying oppositional concepts in liberal democracy – liberalism in foregrounding human rights, democracy in foregrounding equality – Mouffe (2000) constructs democracy as a system enabling a struggle between competing, or agonistic, interests and, is therefore, oppositional, rather than a move towards consensus or overlapping interests (Rawls, 1993). Conflict is core to a pluralist democracy where passions are not marginalised but mobilised through the democratic process. In considering the educational implications for citizenship of Mouffe’s critique of deliberative democracy, Ruitenberg (2009) identifies ‘three areas of critique’ (p. 273) that clarify differences from deliberative models. The possibility of individuals belonging to ‘shifting collective identities’ (p. 273) that are not based, by virtue of the fact that they are shifting, on any essentialist criteria but on shared antagonisms, adversaries or objectives. Examples are the groupings that came together to campaign for cheaper drugs for AIDS sufferers, the challenging of stigma, better and more accurate information about safer sex and greater ethical awareness, and the political campaigns on climate change where groups from the left and the right, libertarian, feminist and socialist, join in rainbow coalitions, facilitated by digital and global communications in ways that would not have been possible over twenty years ago.

The second area of critique is the role of the ‘political’ emotions, which give direction and urgency to thought and action. Third is the need to distinguish between political adversaries and moral enemies, recognising the former as constitutive of the hegemony of social relations, and the motivations for hegemonies to defend their own interests, is distinct from arguments from personal perspectives over right and wrong.
Dissenting collective identities campaigning for rights on technoscientific issues are conceptualised as ‘scientific citizens’ (Elam & Bertilsson, 2003; Irwin, 2001; Irwin & Michael, 2003b; Weldon, 2004). Biological citizenship (Rose & Novas, 2004) incorporates ‘all those citizenship projects that have linked their conceptions of citizens to beliefs about the biological existence of human beings, as individuals, as families and lineages, as communities, as population and races, and as a species’ (p. 2). These concepts of biological citizenship are historically contingent, ranging from racist and eugenicist views about good national stock, through to disability rights movements and contemporary responses, driven by genomics and genetics, to research of ‘biovalue’. The new openings of knowledge about people’s genomes influences insurance companies assessing risk and pharmaceutical companies investing in treatments for genetic diseases. Clusters of collectivities have arisen around biomedical classifications leading to ‘informational biocitizenship’ (p. 6). Rose and Novas (2004) provide varied examples of these collectivities. In the USA the Huntington Disease Advocacy Center runs a website that allows sufferers to update themselves with the latest biomedical information. Hope and optimism are generated by the contributors and dedicated scientists involved in campaigning and, as a result, have secured extra funding from the State. These campaigns are complemented by individuals such as the woman whose husband suffers from Huntington’s and runs a mail list and website that inspires others to campaign and fight for funding and information. They have been joined by researchers serving a common purpose of finding a cure for the disease.

**Educational implications**

Ruitenberg (2009) has identified three areas for development in a programme for citizenship consistent with Mouffe’s conception of radical democracy. First, educating political emotions, as distinct from personal responses to affronts or moral outrages, is about developing a sense of social injustice ‘and the ability to feel anger on behalf of injustices committed against those in less powerful social positions rather than on behalf of one’s own pride’ (p. 277). For example, studying the causes of the Bhopal accident, and how governments in highly dependent economies are more likely to house hazardous chemical plants, can give insights into the injustice of exposing a local populace to these hazards. Second, and closely related to the first point, is elucidating the distinction between moral and political anger. Moral anger is the kind of anger felt when we see an injustice being committed, but political anger is a more distant and abstract notion related to the kinds of political values that underpin a just society. It involves teaching young people explicitly about how power in the political world operates, that ‘keeping politics out’ of an issue is an implicit acceptance of the status quo, and supporting young people’s understanding that the terms of discourse are imbued with hegemonic assumptions, for example, reifying trans-ness as a medical condition rather than a form of identity.

Third, Ruitenberg advocates the development of political literacy. Students need to be able to read social conflict and the origins of injustice ‘in political terms, that is, in terms of disputes about the interpretation of liberty and equality and the hegemonic social relations that should shape them’ (p. 278). These have clear implications for an educational landscape for teacher education. Changing political debates focusing on moral and ethical issues obscure a historical understanding of different ideologies related to the fight for social justice.
There are a number of examples of the kinds of resources which might support such a pedagogy. Components of the Science & Technology Education Promoting Wellbeing for Individuals, Societies and Environments (STEPWISE) (Bencze & Alsop, 2009) course are oriented to STEPWISE activism such as transforming one’s personal conditions, educating others in the school and beyond through accessible media, lobbying power-brokers and, possibly, causing disruptive activities such as clogging up roads with cyclists to prevent the passage of noisy lorries uncomfortable to the neighbourhood. The course is based on a Deweyan inquiry-led approach and on constructivist learning theories where students have the opportunities to express their points of view about what they have learned and to what use they can put their knowledge and skills (Bencze & Alsop, 2009), hence a topic on cell metabolism could be linked to the deleterious affect on health of fast-food outlets.

Santos (2009) produced a chemistry textbook for Brazilian secondary schoolchildren that drives topics through issues of social injustice and inequity, such as a study of agricultural chemistry and inequitable access to food and the conditions of workers in landfill sites.

Although not a school-based activity, Climate Outreach and Information Network (COIN) (http://www.coinet.org.uk/what-we-do/climate-action-groups) supports communities in lobbying and taking action, for example in establishing renewable energy projects in a city, which grow out of concerned groups meeting to discuss their thoughts and feelings about climate change and opportunities for collaborative action. But it does involve understanding the political barriers to change and negotiating them.

*Characteristics of science education for democracy through conflict and dissent*

**Socioepistemic relations.** As in the previous section, knowledge is distributed and emerges through praxis. There is a potential contradiction in the school context in that understanding the causes of oppression as taught through political literacy is likely to have an impact on the institutional framework that makes that understanding possible.

**Epistemology.** As in science education as praxis, there is a strong sociopolitical element to learning. The emphasis here is on political literacy, identifying and analysing the sources of social injustice and both using and producing knowledge to address technoscientific issues related to injustice.

**Controversy and participation in technoscience.** Active participation through various media. The emphasis is on campaigning and activism through scientific citizenship for social and political change

**Pedagogy.** Knowledge is provided on a need-to-know basis. While an understanding of values-based science education is likely to be prominent there will be an emphasis on the causes of social injustice, political knowledge and acting for change.

*Summaries of the four frameworks*

The four frameworks for democratic participation can be summarised in Table 1.
Schools: opportunities and constraints

When the National Curriculum was introduced in England, Wales and Northern Ireland as a result of the 1988 Education Reform Act, citizenship was included as a cross-curricular theme but had limited, non-mandatory status in schools. The election of a social democratic ‘new’ ‘Third way’ Labour government in the UK in 1997 (Giddens, 1998) stimulated renewed interest in citizenship education to address many of the problems that appeared to be associated with recent neo-liberal governments, most prominently the Thatcher-Major governments in the UK, the Reagan-Bush governments in the USA and the Howard government in Australia. The new Labour government identified youth disaffection, devolution, Human Rights, the erosion of the welfare state, globalisation, the transformation in east European politics since the end of the Cold War and ecology and the environment as some of the main issues that a citizenship curriculum could encompass (Osler & Starkey, 2006). Shortly after the election, the political philosopher, the late Bernard Crick, was charged with the task of setting up an advisory group to devise a Citizenship curriculum for schools entitled Education for Citizenship and the Teaching of Democracy in Schools (Crick, 1998).

The first report of the Advisory group on Citizenship stated that ‘We aim at no less than a change in the political culture of this country both nationally and locally: for people to think of themselves as active citizens, willing, able and equipped to have an influence in public life and with the critical capacities to weigh evidence before speaking and acting; to build on and to extend radically to young people the best in existing traditions of community involvement and public service, and to make them individually confident in finding new forms of involvement’ (Crick, 1998, p. 7). The Advisory Group conceived of the Citizenship curriculum as containing three separate but interconnected strands: social and moral responsibility, community involvement and political literacy. Crick elaborated on what he meant by political literacy, it was not voluntarism, pejoratively described as the ‘doing of good deeds’ such as doing jobs for the neighbour, but developing the skills, knowledge and values of participation to bring about change for social justice. What was to be learned had three elements: knowledge and understanding about becoming informed citizens, developing skills of enquiry and approach and developing skills of participation and responsible action (Crick, 2000).

When it came to how the citizenship curriculum might be fulfilled in different subject areas the suggestions for science from the advisory group were rather meagre (possibly rightly unprescriptive) compared with those of history, geography and English. For science they amounted to a total of 11 words: ‘Science and Technology subjects commonly raise ethical issues of social policy’ (Crick, 1998, p. 53), which presumably meant topical issues such as Measles, Mumps and Rubella vaccinations, genetically modified foodstuffs and nanotechnology. Nonetheless, Crick, who was a contributor at the 2000 Association for Science Education national meeting at the University of Surrey in the UK, took the opportunity to stress that the Citizenship curriculum is ‘light touch’. He did emphasise the opportunities for citizenship and science, namely a focus on uncertainty and the tentative nature of scientific knowledge (Crick et al., 2001), procedural concepts (Davies, 2004) such as skills for active debate, elaborated in contemporary science teaching, developing understanding of ideas through argumentation (Erduran, Simon, & Osborne, 2004; Kuhn, 1991; Simon, Erduran, & Osborne, 2006), investigative science, and discussing controversial
socioscientific issues (Levinson & Turner, 2001; Oulton, Dillon, & Grace, 2004; Zeidler & Keefer, 2003).

While these bolstered curricular changes advocated by Beyond 2000 (Millar & Osborne, 1998), similar to other national reform programmes in science, and incorporated in courses such as Twenty First Century Science (www.21stcenturycience.org), as well as supporting discussion and deliberation in citizenship and science, they did not go far enough in reflexively deconstructing the assumptions behind scientific literacy in schools and the barriers for democratic practice (Roth & Calabrese Barton, 2004; Roth & Desautels, 2004) exemplified in the frameworks of science education as praxis and conflict and dissent. Achieving greater democratic practice through the citizenship curriculum in generating social capital has been critiqued in terms of lack of acknowledgement of the role of the State in addressing economic disparity (Gamarnikow & Green, 2000), the social and institutional contexts of achieving democratic practice in an inequitable national school system (Faulks, 2006) and a top-down policy and managerial system that inhibits student voice.

Student/pupil voice

How far do school structures enable scientific-led inquiry in the Deweyan sense in working with teachers/scientists in the commitment to goals of social justice? The role of student voice is core because it reflects the obligations on schools to allow children to have a say on how their schools are governed and how they are taught and learn. Much work has been done on consulting young people about content and teaching in the context of science (Jenkins, 2006). Asking young people what kind of science curriculum they would like (Cerini, Murray, & Reiss, 2003; Osborne & Collins, 2000) and consulting them on general matters of educational governance (Committee, 2002) is not the same as citizen participation in decision-making even if their views are enacted. Students’ views might be appropriated to enhance performativity and to satisfy inspections (Bragg, 2007; Fielding, 2004) rather than encouraging dialogue through democratic participation as equals (Flutter & Rudduck, 2004).

Active participation is not simply operationalised by curricular prescription, however light touch. If schools and classrooms fail to provide democratic spaces for students to participate and act in accordance with their deliberated views then the intentions of the curriculum could be rendered worthless. A review of schools in Europe indicated that very few operate on a basis of deliberative democracy (Huddleston, 2007). Students in the majority of schools have no say in the content of the curriculum, although there is some room for limited manoeuvre through staff-student bodies such as School Councils (Whitty & Whisby, 2007).

Schools in centralised governmental systems such as in the UK are subject to a series of policies and regulations, although there is always some room for mediation and flexibility, often dependent on the worldviews of headteachers and principals. Trafford (2008) has outlined the values that a democratic school would represent, such as an open, relaxed ethos with mutual respect between all involved in the running of the school, the presence of an effective school council with clear expectations and mechanisms for operating, student leadership of school activities and a reflective leadership willing to take risks. But Trafford (2008) identifies a prominent feature of inclusive and democratic schools: the encouragement of critical dialogue wherein all are empowered and self-confident enough to try out new ideas through negotiation.
Since the inclusion of Article 12 in the UN Convention of the Rights of the Child (http://www2.ohchr.org/english/law/crc.htm#art12) there has been considerable research on student voice work. McIntyre, Pedder and Rudduck’s (2005) research is indicative of the problem and scope for theorisation around student participation. Their research consisted of eliciting Year 8 (12- and 13-year-olds) students’ views, including those about science teaching, and the themes which emerged were similar to those of Flutter and Rudduck (2004): interactive teaching for understanding; contextualising learning; a stronger sense of agency and ownership in the students; and social contexts amenable to learning. How far teachers took on board students’ views and made a sustained effort to incorporate them in their teaching depended on the strength of the teachers’ beliefs in, and awareness of, student perspectives. Hence the ethos of the institutional context is crucial in encouraging participation. A significant factor in McIntyre et al.’s (2005) research, however, was the greater articulacy shown by students with a higher learning success prompting the researchers to reflect that the research itself might emphasise and steepen social class distinction and be implicitly exclusive. Where social and cultural capital is contiguous with a school’s ethos, participation is likely to be enhanced, leaving those who do not contribute in this way marginalised and disaffected. Fielding (2004) attempts to explain how such factors operate, noting the problem of promoting student voice for functionalist ends of performativity and the lack of dialogic spaces in which teachers and students talk as equals. Schools therefore need to work within a perception that ‘power relations are unequal and problematic’ (Robinson & Taylor, 2007, p. 8.) and for normative goals of research in student voice to challenge those structures that hinder opportunities for equality of voice and transformative processes of empowerment.

If the school system in the UK, with its top-down managerial structures, is likely to inhibit productive deliberative democratic discourse, then schools are unlikely to be appropriate vehicles to enable this participation to take place, despite the rhetoric of science education reforms. Furman and Barton’s (2006) work has shown that in school, facilitating the student voice as demonstrated in a science research project can actively support identity formation in science, indeed to construct and reconstruct identity through processes of participation. What their research aimed to show is that, with appropriate resources such as technology, voice can be used as a tool both to allow students to communicate on their own terms but also as a means of demonstrating learning. The two students who are the focus of this project are seen as apprentice learners on the periphery of a community of practice (Lave & Wenger, 1991) – one that values knowledge and understanding of science – learning how to negotiate their way towards the centre of this practice so that knowledge of science becomes part of their formative identity and a stimulus for future learning.

One of the two case studies is that of Anthony, who calls himself ‘Reptile Boy’, a student seen as a problem by teachers but one who is popular and has a lively interest in reptiles outside of school. Anthony makes a movie and uses it to validate his knowledge while still demonstrating the playfulness and mock aggression that prevent him becoming too closely incorporated within the school mores. Anthony’s learning, then, has to be seen in relation to his purpose in demonstrating knowledge of science and technology through his discussion of iguanas and the accomplishment of using the video technology while still retaining his school status and popularity. Furman and Barton (2006) conclude with three implications: integrating student experience, which sees expertise as distributed rather than privileged; expanding participation, which allows opportunities for student choices but which recognises that students need to
support these choices through negotiation, reason and evidence; and assessing learning through changes in voice in which learning cannot be dislocated from forms of participative enquiry.

Implications

Globalisation, developments in digital technologies, changing economic power structures, developments in, and threats from, technoscience, new opportunities for knowing (Gilbert, 2005) and growing political disaffection among young people present new approaches for teaching and learning science. These have been met with a policy rhetoric promoting democratic participation in technoscientific issues but, as discussed in the schools in the UK, the necessary structures that need to be put in place beyond the rhetoric are yet to meet the implications of democratic participation. Pedagogies in schools predominantly reflect the deficit framework and, to some extent, democratic deliberation. Both of these modes of teaching aim for some greater participation but they fail to acknowledge the political barriers and the way science policy is implemented, thereby constraining effective decision-making and depending primarily on compliance. My argument is not that the pedagogies associated with these frameworks are misguided, they are not. It is that the underlying political assumptions need to be made explicit to teachers, through professional development courses, and to students. To expect students to be educated towards democratic participation where undemocratic structures still persist in many schools and where the modelling of participation in schools is not reflected in public policy, is only likely to result in hand-waving gestures to practice.

Science education for praxis, and conflict and dissent, enhance the possibilities for critical democratic participation but they involve a radical re-orientation of present science curriculum policy and different ways of producing and using scientific knowledge. The examples discussed demonstrate that such activity is both possible and effective, but it always involves tension and resistance towards the dominant political and institutional context. Recognising the hegemonic role of the curriculum, and the paradoxical nature of stated aspirations towards democratic participation, is itself a move in that direction, which enhances discursive possibilities and transforms what it means to do science.

Notes

1. Merton, writing in 1942, uses the term ‘communism’ rather than ‘communalism’.

Notes on contributor

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