

1.2 School science, citizenship and the public understanding of science

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Quantitative and qualitative studies of the public understanding of science have been conducted in many countries. They provide important insights into the extent to which lay citizens understand a number of important scientific concepts and into the ways in which they seek and use scientific knowledge. This chapter draws upon the outcomes of these studies to identify some of the dimensions of 'citizen science', and to examine their implications for the form and content of school science education.

School science education, citizenship and the public understanding of science are linked in a number of ways. One of the functions of schooling is the development of an informed citizenry and this, at the end of the twentieth century, is widely assumed to require that all students receive an education in science. 'Science for All', an old rather than a new slogan (Brock 1996), now has a global resonance, with many countries revising or reforming school science curricula towards this end, although the impulse for doing so is often principally economic, rather than democratic. Where the latter is invoked, the rhetoric is that citizens need to be 'scientifically literate' in order to be able to contribute to decision-making about issues that have a scientific dimension, whether these issues be personal (e.g. relating to medication or diet) or more broadly political (e.g. relating to nuclear power, ozone depletion or DNA technologies).

Studies of the public understanding of science, however, suggest that achieving a scientifically literate citizenry will require more than the reform of school science curricula, although the importance of such reform should not in consequence be underestimated. In general, quantitative measures of the public understanding of science from a variety of countries and, in some instances, extending over time, present a disappointing picture (Jenkins 1997), although such measures are open to the obvious criticism that they report the extent to which the public knows the science which the scientific community thinks ought to be known. In contrast to these quantitative approaches to measuring the public understanding of science, qualitative studies have focused attention on the needs which different social groups have for scientific knowledge and understanding and on the use that they

make of them. These studies (e.g. Irwin and Wynne 1996) reveal that the relationship of lay citizens and other non-experts to science is much more complex than that normally captured by quantitative surveys of the 'public understanding of science'. In particular, the relationship is interactive, rather than one that can be conceptualized in the beguilingly simple terms of ignorance or rejection of scientific knowledge. In the everyday world of the citizen, science itself emerges not as coherent, objective and unproblematic knowledge, but as uncertain, contentious and often unable to answer many important questions with the required degree of confidence. In some instances, expert scientific knowledge is marginalized or ignored as irrelevant to the problems being addressed. In addition, such knowledge, assuming it exists, is not separated from its social or institutional source and it is weighed alongside other more personal or local knowledge in establishing a basis for action. 'Citizen thinking', i.e. everyday thinking, turns out to be much more complex and less well understood than scientific thinking and, as might be expected, well adapted to decision-making in an everyday world which, unlike science itself, is marked by uncertainty, contingency and adaptation to a range of uncontrolled factors. It is important to note that the implication here is that in many everyday situations 'citizen thinking' may offer a more comprehensive and effective basis for action than scientific thinking, not that the former is in some general way always to be preferred to the latter.

In the context of a scientifically literate citizenry, 'citizen thinking' is intimately related to the notion of 'citizen science', i.e. science which relates in reflexive ways to the concerns, interests and activities of citizens as they go about their everyday business. This chapter draws upon research in the public understanding of science to identify some of the dimensions of 'citizen science' and to examine their implications for the form and content of school science education.

For most citizens, interest in science is linked with decision-making or action. The underpinning notion here is that of science for specific social purposes (Layton *et al.* 1986). These purposes may relate to a variety of contexts and issues, and range from personal matters (e.g. health or child care), employment (e.g. safety at work, risk assessment), leisure (e.g. choosing the best fishing rod, fabric, mountain bike), to individual or organized protest (e.g. at a proposal to irradiate food or flood a valley). A citizen who wishes, individually or as part of a group, to engage seriously in a debate about an issue which has a scientific dimension sooner or later has to learn some of the relevant science. For example, informed opposition to extending an airport runway is likely to demand, as a minimum, familiarity with the logarithmic basis of the decibel scale, the procedures for measuring, recording and monitoring sound levels, and the effect of noise on human health and well-being, together with an understanding of the degree of confidence that can properly be placed in the various relevant measurements. However, matters are rarely as straightforward as simply seeking the relevant scientific knowledge. That knowledge may not be in a form in which it can be used (Layton *et al.* 1993), it may be unavailable (Wynne 1996) or, as in the case of the thalidomide tragedy, not in the public domain. In addition, even when scientific data are available, there may be argument about the methods by which the data were obtained, about the extent to which generalizations

may be sustained, or about the significance to be attached to the findings. The protracted controversy over the harmful effects of lead in petrol involving the Ethyl Corporation and the Environmental Protection Agency in the USA, displays all these features. This has been well described by Collingridge and Reeve (1986), who also discuss its implications for the interaction of science and public policy.

When it is available, the scientific knowledge may also be unnecessarily sophisticated and over-elaborate for the purposes in hand. For example, it is usually more convenient for heating engineers to think of heat as something which 'flows' rather than in terms of the 'more correct' kinetic theory of matter. In much the same way, lay citizens choose a level of explanation which meets their needs. Workers in a computer company, chained to their benches by an earthed metal bracelet in order to prevent damage to sensitive electrical components by the build-up of static electricity, regard electricity as a fluid which can either pile up (static electricity) or be discharged to earth, where it is dispersed or 'lost' (Caillot and Nguyen-Xuan 1995). This 'unscientific' model of electricity enables the workers to function safely and to make sensible decisions when confronted with problems. These scientifically incorrect understandings or misconceptions should not be lightly dismissed. They have been well tested in the context of experience and action and, in those contexts, have served people well. Those, like science teachers, seeking to remedy these misconceptions, might do well to recognize that the tenacity with which they are held outside the classroom probably owes less to cognitive ability than to the proven usefulness of these ideas in the world of everyday experience.

During the course of their personal, working and social lives, all citizens construct a body of practical knowledge, tested and validated against their individual and collective experience. In deciding how and when to act in practical matters that have a scientific dimension, scientific knowledge is considered alongside this other, experiential and personal knowledge base. Wynne (1996) has reported how, in the aftermath of the Chernobyl disaster, the scientific advice offered to sheep farmers in the north west of England failed to accommodate several factors recognized by the farmers as essential to any valid examination of the problem of how long the soil would remain contaminated. These included differences between individual farms even within the same valley, and farmers' own expert knowledge of how and where sheep graze on high ground and about how field experiments could be conducted reliably. Likewise, a study of how elderly people respond to well-intentioned advice about energy conservation revealed that they do so in ways that are much more subtle and complex than might be understood – or even dictated – by a consideration of the nature of energy itself. For these elderly people, the purchase, consumption and use of energy cannot be reduced to a matter of conservation: it is a commodity which has personal, social and financial dimensions (Layton *et al.* 1993). Citizens may also make a positive choice to ignore scientific knowledge that seems, to an outsider, to be of direct relevance to them. Apprentice electricians working at a nuclear power plant, for example, judged it unnecessary to know anything of the nature of ionizing radiation and its associated risks as this was properly regarded as the responsibility, not of the electricians, but of the health physicists employed at the plant (Wynne

1991). What is being stressed here is that, where necessary, citizens construct, from the sources available to them, syncretic bodies of practical knowledge which are well adapted to specific everyday situations. It is, of course, important to acknowledge that while such practical knowledge may be adequate in many contexts, such knowledge can, in other circumstances, be misleading or even dangerous.

It is also important to acknowledge that citizens see the scientific knowledge relevant to an issue with which they are engaged as intimately linked with its social or institutional connections. Citizens ask questions such as: 'From whom?', 'From where?' and 'From what organization or source?' does the knowledge come. Many of the science-based issues with which citizens are concerned are controversial, contentious and at the heart of policy decisions by government, industry or other organizations. The BSE crisis in the UK illustrates very clearly the relationships between the scientific tale and the teller. In a field in which many basic questions surrounding the nature and transmission of the disease remain unanswered and the subject of ongoing scientific debate, government advice about the safety of beef and about how to deal with the problems facing the livestock industry was viewed with considerable scepticism. In a survey conducted in Britain in March 1996, 80 per cent of those surveyed judged that government ministers were more concerned with party politics than with the well-being of consumers (Marris and Langford 1996).

Central to the BSE debate and, more particularly, to the hazards to health associated with eating beef, is the notion of risk. Risk lies at the heart of many science-related policy issues and there are several ways of estimating it. Many of these are both sophisticated and quantitative, and different measures of risk, calculated in different ways, are not always easy to reconcile. In addition, psychological and sociological studies of adults' perceptions of risk do not point towards simple generalizations about how citizens perceive the risks associated with some activity or issue with which they are engaged (e.g. MacGill 1987, Price 1996). Most citizens understand that guarantees of 'absolute safety' cannot be given and they are not, therefore, usually sought. In offering reassurances about contentious issues, such as childhood vaccination or the safety of nuclear waste, the relevant authorities may, therefore, be undermining rather than strengthening the case they wish to promote. What constitutes an acceptable risk depends on many factors. Studies suggest that the risks which people find most acceptable are those which they see as self-imposed or having an immediate impact (e.g. driving a car, consuming alcohol). Conversely, the least acceptable risks are those associated with issues that are seen as the result of the actions of others and as having long-term, perhaps unknown but potentially catastrophic, consequences, e.g. ozone depletion, the storage of nuclear waste.

It will perhaps be clear from the above that it makes little sense to treat 'citizens' as though they were a homogeneous group, or to regard 'science' as an undifferentiated field of activity. At a general level, surveys suggest that in most industrialized countries, adults are more interested in, and more attentive to, medical and environmental rather than other scientific matters, and that the level of attentiveness correlates positively with the duration of formal education. Often, there are also

gender differences, especially in the field of attitudes. In a study of eighteen nationwide surveys in the USA from 1972 to 1990, Trankina (1993) revealed that, irrespective of their educational background, adult women consistently displayed less confidence in science than men. While the confidence of both genders increased with educational level, it also widened as the extent of formal education increased. In another American study, Hornig (1992) explored the responses of men and women to stories of hypothetical new developments in science and technology. In general, women saw less benefit and more risk than men, their concerns focusing upon the social implications of the innovation. It is important to note here that both men and women agreed that increasing scientific knowledge was desirable and that careful control was necessary. Hornig's response to her findings was that they should be interpreted not as a rejection of male-dominated science, but as an affirmation of other aspects of life, notably personal and social relationships, family life and the home. These findings may, of course, be less valid or even invalid in other social contexts.

What are the implications of this complex picture of 'citizen science' for the form and content of school science curricula that seek to promote Science for All? It is important to begin answering this question by recognizing that the *raison d'être* of a science curriculum is science itself. At the end of the twentieth century, this implies more than helping students to acquire an understanding of a number of major scientific ideas, e.g. those relating to the origin of the universe, the theory of evolution and the nature and transformation of matter and energy. It also means more than helping students acquire some insight into how scientific investigations are conducted, a task that is commonly presented as central to school science education but that might be better undertaken by reading Richard Feynman (e.g. Feynman 1998) than by any of the more familiar, if unconvincing, pedagogical strategies that encompass, on the one hand, formal, algorithmic and ritualistic accounts of 'scientific method' and, on the other, highly contrived, expensive and time-consuming laboratory activities, e.g. those associated with the 'experimental and investigative science' that constitutes Attainment Target 1 of the science component of the current national curriculum in England and Wales. Any characterization of the scientific endeavour as the new millennium approaches must take into account that science is now intimately related to production and profit in ways that have allowed Redner (1987) to identify a significant break with the ways in which science has been conducted in the past, and Gibbons *et al.* (1994) to refer to a 'new system of knowledge production' characterized by, among much else, transdisciplinarity, new criteria for quality control and the generation of knowledge within the context of its application. It is this 'new system' that has done so much to transform the social context of science education, and to confront citizens and experts alike with the complex and difficult problems that mark the interface of science and society. School science education needs to respond to this changed social context and to help prepare young people to contribute as citizens to shaping the world in which they will live.

This means constructing science curricula that enable young people to engage in the reflexive ways referred to above, with science-related issues that are likely to be of interest and concern to them. Accepting this entails a number of

consequences. First, school science will need to give somewhat less attention to the minutiae of established physics, chemistry and biology in order to make way for the consideration of issues where the science is less than secure or controversial. The science relating to any long-term physiological or other effects of cannabis, the possession and sale of which is illegal in most but not all countries, is an interesting example. Any consideration of issues such as those surrounding the use and control of cannabis quickly exposes the distinction between knowledge and action, and illustrates the complex interrelationship of science with social policy. It also serves to highlight the need for science teachers to develop some of the skills more commonly associated with other subjects of the school curriculum, e.g. English or History, in which debate and controversy constitute more familiar territory. Equally, it will provide an opportunity to examine several of the significant features of 'citizen science' referred to above, including the social and institutional connections of scientific knowledge, and to explore and promote students' understanding of 'risk' and how it may be assessed.

Second, it is likely that school science curricula in different countries will show a greater degree of variety than is presently the case. Not all science-related issues are global and, if the school science curriculum is to be sensitive to the interests of students, regional or other in-country variations will need to be accommodated. The case of BSE within the UK is an obvious example. It may also be necessary to recognize different interests on the part of boys and girls and to respond appropriately. Central to any response, however, is a degree of flexibility in curriculum control. Unless carefully framed, statutory science curricula, often buttressed by statutory provisions for assessment designed to raise standards and/or enhance accountability, are unlikely to allow schools and science teachers the freedom they need to work in this way.

A third consequence is that the contribution that science can make to education, and thereby to citizenship, is reassessed. Many of the benefits associated with studying science can be exposed as somewhat exaggerated. In 1985, science teachers in England and Wales were advised officially that the 'characteristic of education in science is that it introduces pupils to the methods of science' and informed that 'Each of us needs to be able to bring a scientific approach to bear on the practical, social, economic and political issues of modern life' (Department of Education and Science/Welsh Office 1985: 2, 3). It is perhaps time to acknowledge that science is successful at solving problems only when those problems are scientific or can be cast in a scientific form. As the British Association for the Advancement of Science (BAAS) recognized as long ago as 1917, scientific method, the sine qua non of investigative teaching, is appropriate only when dealing with scientific problems (BAAS 1917: 134). To acknowledge the limitations of science is not in any way to undervalue the scientific endeavour. Rather, it opens the door to a richer understanding of the nature of a profoundly creative and imaginative activity tempered by a scrupulous honesty in the face of experimental evidence. It also permits a re-examination of the relationship between scientific knowledge and other forms of knowledge, whether the latter be the particular local knowledge of a

small community or the more general cosmological theories of non-Western cultures (Pomeroy 1994).

More is involved here than the now familiar courses encompassed by the label 'Science, Technology and Society' (STS). This is partly because many STS courses seem to be attempts to rescue science curricula that are in difficulty and partly because such courses lack a recognizable and legitimate theoretical underpinning (Cozzens 1990). The dimensions of citizen science outlined above offer the rudiments of such a theoretical underpinning, although other models are, of course, possible (see, e.g. Cross and Price 1992).

It is also perhaps important to acknowledge that the notion of citizen science has implications for the research agenda in the public understanding of science. As examples, questions can be asked about the nature, location and effectiveness of the mechanisms involved in the transfer of scientific knowledge between research and other communities, about the articulation of expert and lay understandings of science, and about the ways in which the public understanding of science is understood by science teachers and others.

Finally, a little history and a note of caution are appropriate. Attempts to link school science with citizenship are not new. In the UK, for example, they have surfaced from time to time in a variety of forms that range from the general science movement to the science education for citizenship associated with the political radicalism of J. D. Bernal and Lancelot Hogben. These earlier attempts to steer school science education into significantly new directions have not succeeded in the longer term. In questioning whether contemporary attempts to develop science curricula that will empower future citizens are likely to be any more successful than those of the past, it is perhaps also important to ask whether school science education can any longer encourage the view that the world is much simpler than it really is and, thereby, promote unsustainable claims about the power of science to explain and control. Students are wiser than this, and science educators should not be surprised, therefore, if fewer and fewer of them seem content to embark on a voyage to the idealized, mathematical world created by Newton and Galileo. As Feynman shrewdly observed, 'We have to understand how to handle uncertainty' (Feynman 1998). 'Citizen science' and the school science curriculum seem an appropriate place to start.

Note

Interestingly, a recent report on citizenship in England and Wales confines itself to commenting that 'Science and Technology subjects commonly raise ethical issues of social policy' (Advisory Committee on Citizenship 1998:53).

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