INT. J. SCI. EDUC., 2003, VOL. 25, NO. 6, 759–773

The communication of science and technology: past, present and future agendas

Léonie J. Rennie, Curtin University of Technology, GPO Box U1987, Perth, Western Australia 6845, and Susan M. Stocklmayer, National Centre for Public Awareness of Science, Australian National University, Canberra ACT 0200, Australia

Community learning of science and technology has undergone radical review in the past few years. This paper outlines changes that have taken place in research methods that have addressed the informal learning of science, particularly in the museum sector. We discuss the shift in perspective that has occurred over the past three decades in the public understanding movement, examine some current issues, and suggest future directions for research. The paper concludes with a personal vision for the future of community learning about science and technology.

Introduction

In general terms, this paper is about community learning of science and technology. For some time there have been two perspectives to this theme. The first, often called informal science and technology education, has usually addressed the outcomes of situations where community members choose to visit an institution such as a museum, or participate in other activities, such as a science-related hobby, where learning about science and technology occurs. The second perspective has come under the general umbrella term of the 'public understanding of science' and is concerned with what members of the community actually know or understand about science. Although clearly related, these perspectives have remained separate, with their own research agendas and traditions. Recently, there have been signs that these two perspectives may be moving closer together, towards a general concern with how and why people in the community learn about science and technology, and how this learning might be facilitated.

In this paper, we examine each of these two perspectives and the kinds of research and theoretical bases that have underpinned our understanding of them so far. We then look at how these two perspectives might be moved closer together and what kind of research might facilitate this. To achieve this overall aim, we begin by describing the scope of learning in science and technology education in out-of-school settings to build a framework for discussion. We will trace some of the paradigmatic shifts in thinking about informal science and technology education, enabling us to move to the related issue of the public understanding of science. We

International Journal of Science Education ISSN 0950–0963 print/ISSN 1464–5289 online © 2003 Taylor & Francis Ltd
http://www.tandf.co.uk/journals
DOI: 10.1080/09500690320000766670

will outline the research and theoretical directions that may effectively be pursued in the future to promote people's involvement in and understanding of science and technology. We will conclude with our personal vision of a future in which people are encouraged and able to engage in science and technology education for themselves.

The scope of science and technology education in out-of-school settings

There is no doubt that learning in science and technology occurs outside of school through real world experiences, and these experiences contribute significantly to people's knowledge, understanding and attitudes about science. This was stated clearly in the recent policy statement of the National Association for Research in Science Teaching Ad Hoc Committee on Informal Science Learning (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003), which recognizes the breadth of science learning.

> Learning rarely, if ever, occurs and develops from a single experience. Rather, learning in general, and science learning in particular, is cumulative, emerging over time through myriad human experiences, including, but not limited to, experiences in museums, schools, while watching television, reading newspapers and books, conversing with friends and family, and increasingly frequently, through interactions with the Internet. The experiences children and adults have in these various situations dynamically interact to influence the ways individuals construct scientific knowledge, attitudes, behaviours and understanding. In this view, learning is an organic, dynamic, never-ending, and quite holistic phenomenon of constructing personal meaning. This broad view of learning recognises that much of what people come to know about the world, including the world of science content and process, derives from real world experiences within a diversity of appropriate physical and social contexts, motivated by an intrinsic desire to learn (p. 109).

Every person has opportunities for learning science and technology in out-of-school settings. Some of these opportunities will be more structured than others, some will be initiated entirely by the persons themselves. Further opportunities will be the consequence of deliberate targeting of particular groups of the community. Here are just four examples.

Example 1: visiting exhibitions of various kinds. People may visit a museum exhibition about Pharaohs, say, with the specific aim of learning more about a particular aspect of life in those times, or the embalming processes used in mummification, or simply to be entranced by their first sight of a real mummy. Other kinds of learning can happen incidentally; for example, an abiding memory of one author's visit to an exhibition entitled 'Life and Death Under the Pharaohs' is the realization of the extent to which the fashioning of sarcophagi, stele, and various household artefacts was limited by the properties of the available materials from the earth, such as granite, limestone and alabaster.

Example 2: pursuing interests and hobbies. People who pursue a science-related interest or hobby have a great deal of knowledge and understanding about it, but rarely do they think of this as knowledge and understanding about science. The power of this knowledge should not be underestimated, as much of our basic knowledge about flora and fauna in Australia and other countries comes from sharing information of this kind. For example, McKeown's (1952) classic text on Australian spiders is liberally illustrated with excerpts from letters written to him by amateur naturalists in the first half of the last century, sharing their detailed observations of the number, kind and behaviour of spiders in their garden.

Example 3: needing information to interpret one's circumstances. Often people need to obtain information about circumstances in their own life in order to make decisions about appropriate action to be taken. The stimulating factor might include anything from the diagnosis of a medical condition, to noticing that the leaves on garden roses have suddenly withered. There is a range of sources of information available, including books, the Internet, fact sheets, community services, and specialists in particular areas that might be consulted on these occasions.

Example 4: community education programmes. An important source of knowledge about science and technology is the deliberately targeted community education programme designed to apprise the public of information they need to know (or in the case of much advertising, are thought to need to know). Informing travellers of quarantine regulations and the reasons for them is one example; another is the Slip! Slop! Slap! – slip on a shirt, slop on some sunscreen lotion, and slap on a hat – slogan of the publicly funded educational campaign in Australia to reduce the incidence of skin cancer.

How much do we know about learning in these different examples of science and technology education? Not all have been researched to the same extent, and they have been researched from different theoretical perspectives using different conceptual frameworks. For each of these examples, however, the 'learner' chooses to seek or take note of information that comes from authoritative scientific sources – the 'experts'. Of course, in some of these cases an interactive dialogue can result, particularly in the instance of pursuing a hobby. But, almost always, the learning is a one-way, transmission process. Indeed, the term 'informal science education' connotes that the public has the need, or the desire, to be educated. In the first three examples, the learner initiates the process by accessing the source. In the fourth example, the information is placed before the learner in a random and less organized way. Unlike formal education, however, the learner in all these examples has the option to choose freely what is interesting and relevant, and follow-up accordingly.

Extensive research has been conducted into learning in science museums (here the term is used generically to refer to institutions such as the traditional museums, science museums, science centres, art galleries, aquariums, botanic gardens, interpretative centres, and other such organized places that usually have an educational aspect to their mission statement). Of course, as out-of-school institutions with potential for learning, they are among the oldest, so perhaps it is not surprising that most of the early research in the field has been based in this environment.

In contrast, the subject of the second example, learning for self-interest, is often pursued in a solitary manner and probably has attracted the least amount of research in terms of studying what and how people learn. Much of the learning is for personal pleasure, not for personal need, yet no one would deny that the outcomes are educational.

The third and fourth examples differ in terms of the motivation for the communication of information. Example 3 describes occasions where people are seeking scientific information on their own volition because they need it to deal with a personal issue. In contrast, the information about quarantine and skin cancer, used for Example 4, is being offered to people for 'their own good' and they can choose whether or not to take notice. There is a considerable body of research about how people interpret and use science and technology communicated in this way, much of it under the umbrella of the 'public understanding of science'.

In all of these examples, and especially the last two, communication of science and technology is assisted by the media, which acts as a source of information as well as the mode by which it is transferred. The nature of media has been changing and expanding remarkably through the twentieth century, and there is little doubt that its pervasiveness now makes it the most influential avenue for education about science and technology available in out-of-school settings (Barns, 1989). One might easily imagine that we have the best-educated population in terms of science and technology that the world has ever had. But have we? The answer depends on what such a question really means. It could mean, how much knowledge and understanding do the population have about science and technology? Or, do people have the information they need to make science and technology-based decisions in a responsible way? Or, if not, do people know where to get the information they need? We might also ask, do people want to be involved in decision-making, or do they want to leave decisions to 'the scientists'?

In the remainder of this paper we consider these questions. We begin by reviewing the two major strands of research relating to science and technology in out-of-school settings. The first examines the research base that centres on opportunities to learn from places like museums. For many decades, studies of learning in museums have yielded information about what people learn informally. This research has evolved, however, from assessing learning in terms of 'target' knowledge to a broader view of what constitutes valid learning, incorporating constructivist and socio-cultural ideas. In the next section, we review the evolution of this research, which constitutes the largest body of information on the learning of science in these environments.

Learning in museums and similar institutions

Museums have long been sites for people to learn, but their nature has changed. The earliest museums were about 'things', people's nature collections on display for others to look at. Modern museums have a much broader base, with many of the dioramas of the past replaced by visually linked displays that tell stories, not just of a scientific nature, but the social aspects of it as well. Science museums in particular seem to be developing socio-scientific installations as part of their evolution (Pedretti, 2002). Computer-based interactive exhibits are providing another dimension to the kind of learning experiences available in museums. Furthermore, the range of purposes of museums is expanding; consider the rapidly increasing numbers of corporate museums, for example, many of which link science with society and have an explicit aim to educate the public about the company (Kraus, 2000).

Research into what people learn from museums began early in the twentieth century. For example, Melton, Feldman, and Mason (1936) report the outcomes of 5 years of research at the Buffalo Museum of Science to determine the structure of the most effective museum visit in terms of knowledge gain. Like the diversity in the museums themselves, the research base has increased exponentially. Rennie (2001) made an elementary categorization of research into visitor behaviour in museums, pointing out that, with few exceptions and regardless of whether the research is exhibit-related or visitor-related, the researcher must collect data from visitors themselves. Research related to whether exhibits 'work' soon had a well-developed evaluation base (see Screven (1984) for an overview of exhibit evaluation, and Pearce and Moscardo (1985) for an evaluation of visitor responses to a range of environments), but continued to expand from its early interest in summative evaluation to formative evaluation and, even more recently, to front-end evaluation, where the key issue is whether a yet-to-be-developed exhibit(ion) will work.

Research into visitor learning, which looks at what visitors do and whether they learn, has developed even more diverse methods and is much more relevant to our concern here. Melton *et al.* (1936) used pre-test–post-test control group designs in their studies, but they recognized that control groups also had to visit the museum, believing that comparing the knowledge of children who spent the same amount of time studying the same material from a book, for example, was fruitless. The museum visit could be rendered more or less effective than the book experience, Melton *et al.* argued, depending on the way it was used. Instead, 'we have assumed that the museum has a unique contribution to make, and we have proceeded to investigate ways in which this contribution can be most fully realised' (Melton *et* al., 1936, p. 2). There are two important points in this statement; the belief underlying the research, and the nature of the research design.

Fundamentally, there has been a major shift in thinking about the visitor experience. Certainly, the museum has a unique contribution to make (see Falk, Dierking, and Holland (1995) for a consensual description of this contribution), but it is now understood that this contribution is dependent not only on the nature of the museum, but also on the nature of the visitor. This means that research has to take into account attributes of both the institution and the visitor.

This realization has its roots in theories about how people learn and, while there is still a range of competing theories, there seems to be a coalescence of themes that, broadly, might be referred to as constructivism and socio-cultural theory. The first has had a particularly strong influence in science education and its history can be traced in journals such as this one. The influence in the museum context has been described by Roschelle (1995) and Hein (1998). Socio-cultural approaches to thinking about learning have been developed in the formal educational environment but also in out-of-school settings (for example, Hull and Schultz (2001) have recently reviewed the field in the context of literacy). A socio-cultural framework has been developed by Schauble, Leinhardt, and Martin (1997) to guide research by members of the Museum Learning Collaborative (http://mlc.lrdc.pitt.edu/). Of course, not all of this research is specific to learning in science and technology, but the methods being developed have application in learning about science (for example, Ash, 2002; Crowley & Galco, 2001).

Different ways of thinking about learning in museums have required different ways of doing research. Melton *et al.*'s (1936) work was exemplary for its purpose but, once it was recognized that the visitor is an active agent in the museum experience, research questions had to change. In fact, museum research is quite eclectic, having drawn from a range of disciplines and methods including ethology, ethnology, anthropology, psychology, and sociology, as well as education. Much research has focused on how families behave in the museum setting, and Diamond (1986), Dierking and Falk (1994) and McManus (1994) have provided notable reviews. Another strand of research has studied the learning of individuals as they interact with exhibits (Feher, 1990; Feher & Rice, 1985) and how they form mental models of what is happening. The notion of mental models as a tool for describing learning in museums is receiving renewed attention (Gilbert & Stocklmayer, 2001; Stocklmayer & Gilbert, 2002).

There is now a very large body of research about science learning in museums and other out-of-school sources, represented by a range of reviews (for example, Bitgood, Serrell, & Thompson, 1994; Lucas, 1983; McManus, 1992, Pedretti, 2002; Ramey-Gassert, 1997; Rennie & McClafferty, 1995, 1996), several edited books (for example, Crane, Nicholson, Chen, & Bitgood, 1994; Falk, 2001) and special issues of the *International Journal of Science Education* (Lucas, 1991), *Science Education* (Dierking & Martin, 1997) and the *Journal of Research in Science Teaching* (Feher & Rennie, 2003).

A comprehensive model for thinking about learning in museums, put forward by Falk and Dierking (2000), has found considerable utility. These authors draw together the research base to present their Contextual Model of Learning, a re-casting of their earlier Interactive Experience Model (Falk & Dierking, 1992). The Contextual Learning Model distils eight key factors that affect learning in three contexts. The personal context includes motivation and expectations; prior knowledge, interests and beliefs; and choice and control. The socio-cultural context includes within-group socio-cultural mediation and facilitated mediation by others. Finally, the physical context includes advance organizers and orientation, design and reinforcing events, and experiences outside the museum. It can be seen that time is an essential element in properly addressing some of these factors. Learning is not an event, it is a process; albeit we have all experienced those 'tiny epiphanies' (Friedman, 1995) when the light of learning dawns. We build on what we know, and that is one of the reasons why it is so difficult to assess the impact of out-of-school learning, because our experiences in the present remind us of our experiences in the past and change the nature of our experiences in the future.

Recently, the Ad Hoc Committee for Informal Science Education of the National Association of Science Teaching suggested six directions for furthering research in this area (Dierking *et al.*, 2003). These directions were discussed by Rennie, Feher, Dierking, and Falk (2003), and can be summarized briefly as follows. Extending and enhancing research in out-of-school settings requires examining the precursors to the actual engagement in learning as well as the learning itself, taking into account the physical settings where learning takes place, exploring the social and cultural mediating factors in the learning experience, promoting longitudinal research designs that recognize learning is cumulative, investigating the process of learning as well as the products, and expanding the variety of methods used to carry out our research. Pursuing these avenues will expand our understanding in these areas, but there is still a long way to go.

The evolution of visitor research already described has parallelled the development of educational theories that, increasingly, take note of the personal aspects of learning. Similarly, the prevailing view of the public as receptors of scientific knowledge has changed, albeit more slowly. Our third example, presented earlier, where people need information to deal with a specific issue, has been examined over the past two decades through case histories in various media that have led to a recognition that ordinary people, when required, can develop expert understanding of a specific scientific domain (see, for example, the ongoing story of

Lorenzo's oil (*The Guardian* Online, 2002) and the many cases reported by Irwin and Wynne (1996).

These cases have contributed to a revision of the goals of the 'public understanding' movement, towards a more equal contribution both from scientists and the public. The history of this revision is outlined in the next section of this paper.

Public understanding versus public engagement

For three decades, much attention has been paid to notions of scientific literacy and the cognitive domain of public knowledge. In the 1980s and early 1990s, strong arguments were put forward in favour of an increased public understanding of science (PUS) (see, for example, Durant, Evans & Thomas, 1989; Evans & Durant, 1995; Hirsch, 1987; Thomas & Durant, 1987; Trefil, 1993). To a greater or lesser extent, these arguments entailed better understandings by the public of the key concepts that science has produced, of the methods of enquiry used in science, and of the social processes by means of which science takes place (Millar, 1996). This fairly narrow model of public understanding focused only on what the public knows and hence, by subtraction, what the public does not know. It has been questioned by Wynne (1993), who first coined the term 'deficit model' to describe this approach to scientific literacy. Wynne argued that the 'un-reflexivity of science, and the corresponding lack of recognition of the reflexive dimensions of public responses to science, combine to obstruct practical progress in PUS' (1993, p. 323).

Also, Layton, Jenkins, MacGill, and Davey (1993) published their detailed studies of four groups of people and how they dealt with information about science and technology in their particular context. They found that people selectively filter and re-structure scientific information into a form they found personally meaningful and useful. The results showed conclusively that a deficit model of public understanding of science had little value because the 'public' simply do not understand science on science's terms, but on their own terms. This includes understanding of scientific ideas, as has been shown by the vast literature on alternative conceptions, but it extends much further, into issues of understanding risk (for example, Gregory & Miller, 1998), pride in local understandings, and cultural and societal values (for example, Aikenhead, 2001; Harding, 1991).

Profound changes have taken place over the past 5 years in the way in which the world of science views the public. There is no clearer reflection of these changes than in the deliberations of the science communication forums held annually at the Festival of the British Association for the Advancement of Science. In 1998, the forum devoted its time to an analysis of what exactly was intended as the goal for PUS (see *SCAN*, 1998). The Forum expressed the wish to settle on 'a core definition of PUS' and to develop 'robust criteria and methods to evaluate PUS activity'. In 2002, the Forum focused on Public *Engagement* in Science and Technology and, in the wake of the House of Lords (2000) report and the report of the Office of Science and Technology and the Wellcome Trust (2001), agreed that PUS was an outdated concept that implied a one-way communication from the science community to the public.

The situation in 1998 was summed up by Gregory and Miller in their comprehensive book *Science in public*:

> . . . does the public understanding of science movement in the late 20th century in any way merit the label 'initiative' or has it all been said before? . . . there appears to be a genuine recognition on many sides that we cannot enter the next millennium with a society in which the 'scientifically literate' are increasingly distanced from those who know nothing and care less about one of the great cultural achievements of modern civilisation. For their own motives, government, the scientific establishment, and individuals have involved themselves in the public understanding movement in such a way that there remains room for dissident voices not only to be heard but also to influence the way in which the debates about science and its role in society will go. There is even a glimmer of acknowledgment that all parties involved have a lot to learn about each other. As yet, we have no idea whether the current spate of activity makes any difference to anyone . . . but for the time being at least, the public-understanding-of-science industry believes that what it is doing really matters and is pushing its product to a public that, sometimes at least, seems to agree. (1998, p. 18)

Just 2 years later, the House of Lords (2000) report was describing the PUS movement as arrogant:

> It is argued that the words imply a condescending assumption that any difficulties in the relationship between science and society are due entirely to ignorance and misunderstanding on the part of the public; and that, with enough public-understanding activity, the public can be brought to greater knowledge, whereupon all will be well. This approach [27] is felt by many of our witnesses to be inadequate; the British Council went so far as to call it 'outmoded and potentially disastrous'. (2000, p. 140)

With extraordinary speed, the tone of debate in Europe has changed to one of dialogue, openness and accountability. Yet decisions about science and technology education and informal learning, for the many people whom these areas aim to reach, are no closer to resolution than before. It is not the province of this paper to examine science and technology education, *per se*. Rather, we wish to pose some questions that need to be answered if we are to move forward the public's involvement in areas ranging from decision-making about science, technology and research to the uncomplicated enjoyment of scientific knowledge for its own sake.

What is reasonable for people to know about science and technology?

The notion of science literacy, in particular, implies some foundation knowledge of science that may be measurable. As Gregory and Miller (1998) explained, there is a perception that the 'scientifically literate' constitute one body of people, and those who 'know nothing and care less', another. The original 'public understanding' idea was based upon this premise and this idea was reinforced after publication of a survey by Durant *et al.* (1989). The survey was conducted with members of the public in Britain and the US, and asked questions about general science content and the nature of science. Results of the survey indicated 'cause for concern' in that most of the public were found to understand 'not much' science (Durant *et al.*, 1989, p. 11). Although the findings were questioned by Gaskell, Wright, and O'Muircheartaigh (1993), who explored the issue of context effects on surveys such as these, negative comments about the public's scientific literacy have persisted almost to the present time.

Given this perceived ignorance of the public, it is of interest to examine the reaction of practising scientists to the original Durant *et al.* (1989) questionnaire. This has not previously been reported, but is the subject of ongoing research. Over the past few years, Australia's National Centre for Public Awareness of Science has been conducting workshops for practising scientists of all disciplines and from many different countries of origin including the UK, the US, Australia, New Zealand and many countries of Asia. The subject of these workshops is effective communication with the public. The workshop facilitators have found that it is a common view among scientists, particularly older ones, that responsibility rests with the public to learn more science. Indeed, one scientist expressed the view that it was the *duty* of the public to learn more science, given the benefits they obtained from it. A small part of these workshops has therefore involved a consideration of the issues of understanding, literacy and awareness. Part of the Durant *et al.* (1989) questionnaire has been used to provoke discussion.

The scientists were given a section of the questionnaire and asked to complete it before making comments. To date, some 193 scientists have taken part, from disciplines including physics, chemistry, environmental, agricultural and medical sciences. Although this research is still in progress, preliminary results indicate that, on many questions, the scientists were unsure of their answers or were deeply critical of the questions. Not one of the scientists felt completely confident of their answers to every question and many admitted frankly to ignorance of several questions outside their discipline. There was no question on which all the scientists were correct.

Significantly, these findings indicate that, when outside their own discipline, scientists often are no less ignorant than the general (presumably lay) public. Given this, we might ask: Does lack of scientific knowledge really matter?

The scientists themselves are deeply divided on this issue. Some are 'shocked' at the public's ignorance but many recognize, in their own inability to be certain of their answers, that the public cannot be expected to retain facts that are not useful.

Creating a dialogue with the public

As we have said, the argument for PUS has shifted away from tests of public *knowledge*. Rather, there is a new emphasis on strategies such as focus groups, consensus meetings, and so on, to probe public *opinions* of important current issues. In the area of informal learning, museums are becoming less focused on transmission of content. Instead, they are setting what might be called 'learning agendas', which recognize and take into account the many different ways in which learning can occur. These are exciting new steps along the road to better understanding of the public's interaction with science and technology and how they can take control of their own learning. The term 'dialogue' is now current and seeks to produce a better balance between the 'two sides' of the debate.

In our view, however, there is still little idea where all this is going in terms of 'educating' people in science and technology. What do educators in science really want? What does the public want? In fact, are these useful questions? Fundamental to progress, we believe, is some agreement as to the ultimate goals of these different approaches to learning science and technology. There must be a much deeper research agenda to understand how to make the most of occasions where the world of science interacts with the public. However, the idea of public 'engagement', may not be the most helpful term to describe such an agenda.

'Engagement' is an interesting term with many shades of meaning (Brown, 1993). It can imply an equal contract, or (less pleasingly) a contract to serve. It may signify holding one's attention for a period of time. Notably, it is also a term of war.

Which variations of engagement do we really mean? In imagining this new relationship between science and the public, it is hard to avoid the old, top-down connotations of PUS because the idea of 'engagement' still seems to place responsibility on the *public* to make the overtures to learn more about science and technology. There is, however, an underlying implication that the outcomes may be unexpected.

Our view is that the notion of 'science and technology's engagement with the public' may better represent the way forward. It is very difficult at this time to make predictions about how this can happen. Formal and informal long-term goals must be set for students who are still in school, but immediate steps must also be taken to approach and involve out-of-school adults. We have few mechanisms to do this. It is vital to undertake much more research in order to understand the diverse and multicultural groups that constitute our adult populations, how to reach them, and how to make science and technology accessible to them. To conduct such research without any idea of the ultimate goals is futile. In the meantime, public criticism of science and technology will continue.

Sjøberg (2002) comments that those who see public criticism and scepticism of science and technology as implying a lack of understanding need to realize that 'communication is a two-way process'. He raises a series of questions about science and technology education in Europe. Sjøberg's questions are centred around schooling (2002, p. 4). He asks whether we should favour early specialization, identification and recruitment of the more able, or have a comprehensive system for all. Should one maximize students' individual freedom to choose? How should one support life-long education and develop adult education and on-the-job training? These questions relate to what should be taught, to whom, and when. They are, however, relevant to this paper, in that Sjøberg concludes by saying: 'One will need to look beyond the education system and involve different stakeholders. There is a need for context specific reforms with a multi-dimensional approach and long-term implementation' (2002, p. 5).

In a strikingly similar vein from the museum perspective, Muscat argues that 'a more strategic, coordinated, and successful infrastructure for free-choice learning would be a powerful partner with formal education and the scientific establishment in promoting science literacy in the next [twenty-first] century' (2001, p. 204).

The need for involvement of people beyond the formal system is at the heart of our argument for a review of the notion of there being scientific facts that are reasonable for people to know. What is needed is urgent debate and reform. Should we concentrate on science as process, science as history, science as uncertainty? We leave these questions for the formal sector to decide. In the meantime, we will concentrate our recommendations on what we already know about adults who learn science outside of school.

What do people do when they learn from out-of-school sources?

Adults learn science because they want to, or they need to. As the examples given earlier demonstrate, they seek knowledge purposefully by pursuing their own interests, or they learn by accident, as the opportunity arises. Learning may be in any of the domains identified earlier in this paper and none is intrinsically better than others. Different interest groups, however, have different views of successful learning. We conjecture that in the view of museums, for example, ideal science learning may include broadening or deepening cognitive understanding of the topic in question. In the view of the government, science learning may involve conversion of ideas to a point of view that facilitates economic or technological advances. For example, in his document *A chance to change*, Robin Batterham, Australia's Chief Scientist, states:

> One of the foremost tasks for the public sector SET [Science, Engineering and Technology] base . . . is to strengthen the general knowledge base to ensure that innovative activity is maximised across universities, government funded agencies and, particularly, industry. . . All Australians must be provided with the basic knowledge and skills they need to operate in a knowledge-based society. (Batterham, 2000, p. 30)

Some issues are of high environmental importance and require behavioural change on the part of interest groups. Successful change may be assumed to constitute 'learning' for those desiring such change.

In terms of deliberate attempts to provide learning opportunities to the public, there seems at this time to be two aspects to facilitating public engagement. On the one hand, there is the seeking and involvement of the public's views through debate and consensus; and on the other hand, there are the outreach activities of science museums, science festivals and so on. While both aspects refer to engaging the public in science and technology, the first more actively seeks public input to debate. Whenever the debate includes members of the public, it is now widely acknowledged that there must be a genuine intent to respect, recognize and incorporate their views (for example, Keen, 1997; Keen & Stocklmayer, 1999; Sless & Shrensky, 2001). As Peter Briggs, then Chief Executive of the British Association for the Advancement of Science, explained, this is not simple:

> It is easy enough to agree that dialogue is important, but more difficult to do and not easy to understand if scientists take it seriously . . . Participants must respect all the others involved. Allow them to put their point of view. Listen as well as speak. Empathise – learn to put oneself in the shoes of others – something that is not easy, especially if you believe yourself to be right . . . Dialogue of the deaf is no dialogue at all . . . The agenda for dialogue should be set by the public, not by the scientists. It is vital to address real public concerns, not just the topics that scientists think the public should be interested in . . . (2001, p. 8)

The second aspect, the domain of outreach activities, seems to focus more on sharing; sharing science knowledge for interest and general usefulness, and sharing science knowledge about issues.

As we have outlined in an earlier part of this paper, the museum sector has to some extent addressed evaluation of their activities, but other sectors such as festivals, the media and so on are very far behind. The research needed in this area is, to say the least, challenging. We know very little about what is interesting or useful to the public (recognizing, of course, that the public is both heterogeneous and diverse), and we do not know how to reach the people who are 'unengaged'. Little is known about how much science and technology is learned from television, from the Internet, and from books. In the museum domain, we certainly know a little more, but these are interested adults who are purposefully participating. This brings us to our last major point.

What research is required?

From the research described, we know that adults visiting science and technology museums, even when they profess little or no previous science education, are intrigued and entertained by the visitor experience. We know that the links they make to their own past experiences are critical to this enjoyment and underpin all kinds of learning. We know that complex explanations, difficult instructions or very high-tech exhibits inhibit their involvement. For this group, the learning is often different from the intent of the exhibit designer but nonetheless meaningful. Highly contextual exhibits may be useful in some instances, but inhibiting in others.

If there *is* a body of scientific knowledge that is desirable for people to have, it is relatively easy to proffer experiences around this knowledge through the outreach of museums and science festivals. To reach other people who do not avail themselves of this outreach, however, is a problem not well understood by the museum sector. If there is important knowledge to be shared, such as the need for immunization of children, how do we set about making it known in the wider community? Too often, governments and scientists bemoan the high-profile activities of anti-something activists who are vocal and persuasive. But these activist groups succeed because they go where the clients are, and make themselves heard by a wide cross-section of the community. So far, those representing the world of science have not done that. Indeed, there seems to be little idea of how to begin.

There is still an emphasis in the public arena on talking to the converted, with some attention given more recently to talking with the concerned. In many cases, such as the problems with BSE, genetically modified foods, destruction of native forests, or foot and mouth disease, this talking is too late. There needs to be a strategy of foresight, helped by research into new ways of reaching those who currently are indifferent. A gulf will remain, however, unless scientists are brought into the discussion as players, not captains in the debate. In this regard, there is as yet no explicit recognition of the *public's* knowledge being of value to scientists. This may be the greatest barrier to overcome on the part of science, because it often leads to rejection or indifference by public stakeholders.

These points relate to the desire by many scientists to share knowledge, or the need to communicate national concerns. Another key question, however, has not (as far as we are aware) been addressed in any research to date. This is the issue of what the public *wants* to know. Public understanding, engagement or any other similar term, implies that the science knowledge is there, waiting for the public to join in. We suggest, however, that the more profitable process in the longer term will be to find out what is needed, where, and by whom. In making this recommendation, we do not underestimate its difficulty. But if science and technology are to engage the public, we need to understand what individuals within the community, in all their diversity of backgrounds, environments and occupations, would like to know. As Briggs (2001) has suggested, the public should be determining this part of the scientific communication agenda, not the scientists.

At the outset, we indicated that, in general terms, this paper was about community learning of science and technology. We gave examples of such learning to illustrate the variety of settings, outcomes and the reasons why learning might occur. We overviewed the well-established research base in the museum context, the traditional source of out-of-school learning, and the directions it is taking. We also recognized the different approach taken in the field known as the public understanding of science, which looked at what the public knows about science. Attention was drawn to the major theoretical shift occurring in this field to take account of the role people play in determining what science they are willing to learn and how they learn it. We attempted to bring together ideas about what people might choose to know and understand and how the science community and other purveyors of science and technology might best encourage the involvement of the public. Essentially, this involves two-way communication and, so far, there is limited understanding about how this can be done. Clearly, research is needed.

We summarize with our personal vision for public involvement with science and technology. We envisage:

- People who feel that science and technology lie within their interest and their personal lives.
- People who feel that the nation's science is both their property and their responsibility.
- People who are able to access new knowledge in science and technology, and understand how it will affect their lives
- People who feel comfortable about processing relevant scientific information so that their personal areas of interest are well served.
- People who feel that their own knowledge and concerns are valued by the scientific community.

If we can achieve a community with this level of involvement in science and technology, we may even see members of Government who are informed and interested in the scientific issues of the day, the concerns of the scientific research community and the public, and who acknowledge their own responsibility to promote and support better dialogue with the community.

References

Aikenhead, G. S. (2001) Science communication with the public: a cross-cultural event. In C. Bryant, M. Gore, & S. Stocklmayer (Eds.), *Science Communication in Theory and Practice* (pp. 23–45). Dordrecht: Kluwer International.

Ash, D. (2002) Negotiation of biological thematic conversations in informal learning settings. In G. Leinhardt, K. Crowley, & K. Knutson (Eds.), *Learning conversations in museums* (pp. 357–400). Mahwah, NJ: Erlbaum.

Barns, I. (1989) Interpreting media images of science and technology. *Media Information Australia*, 54, 22–29.

Batterham, R. (2000) *A chance to change*. Canberra: Department of Industry, Science and Resources.

Bitgood, S., Serrell, B., and Thompson, D. (1994) The impact of informal education on visitors to museums. In V. Crane, H. Nicholson, M. Chen, & S. Bitgood (Eds.), *Informal science learning: what research says about television, science museums, and community-based projects* (pp. 61–106). Dedham, MA: Research Communication.

Briggs, P. (2001) *From monologue to dialogue – progress in science communication in Britain*. Plenary address to the Australian Science Communicators Conference, Sydney, Australia, September.

Brown, L. (Ed.) (1993) *The new shorter Oxford English dictionary*, 3rd ed. Oxford: Oxford University Press.

Crane, V., Nicholson, H., Chen, M., and Bitgood, S. (Eds.) (1994) *Informal science learning: what research says about television, science museums, and community-based projects*. Dedham, MA: Research Communication.

Crowley, K. and Galco, J. (2001) Everyday activity and the development of scientific thinking. In K. Crowley, C. D. Schunn, & T. Okada (Eds.), *Designing for science: implications from everyday, classroom, and professional settings* (pp. 393–413). Mahwah, NJ: Erlbaum.

Diamond, J. (1986) The behavior of family groups in science museums. *Curator*, 29, 139–154.

Dierking, L. and Falk, J. (1994) Family behavior and learning in informal science settings: a review of research. *Science Education*, 78, 57–72.

DIERKING, L. D., FALK, J. H., RENNIE, L. J., ANDERSON, D., and ELLENBOGEN, K. (2003) Policy Statement of the 'Informal Science Education' Ad Hoc Committee. *Journal of Research in Science Teaching*, 40, 108–111.

DIERKING, L. D., and MARTIN, L. M. W. (1997) Guest editorial. *Science Education*, 81, 629–631.

DURANT, J. R., EVANS, G. A., and THOMAS, G. P. (1989) The public understanding of science. *Nature*, 340, 11–14.

EVANS, G., and DURANT, J. (1995) The relationship between knowledge and attitudes in the public understanding of science in Britain. *Public Understanding of Science*, 4, 57–74.

FALK, J. H. (Ed.). (2001) *Free-choice science education: how we learn science outside of school*. New York: Teachers College Press.

FALK, J. H., and DIERKING, L. D. (1992) *The museum experience*. Washington, DC: Whalesback Books.

FALK, J. H. and DIERKING, L. D. (2000) *Learning from museums: visitor experiences and the making of meaning*. Walnut Creek, CA: Altamira Press.

FALK, J. H., DIERKING, L. D., and HOLLAND, D. G. (1995) What do we think people learn in museums? In J. H. Falk & L. D. Dierking (Eds.), *Public institutions for personal learning: establishing a research agenda* (pp. 17–22). Washington, DC: American Association of Museums, Technical Information Service.

FEHER, E. (1990) Interactive museum exhibits as tools for learning: exploration with light. *International Journal of Science Education*, 12, 35–39.

FEHER, E., and RENNIE, L. J. (2003) Guest editorial. *Journal of Research in Science Teaching*, 40, 105–107.

FEHER, E. and RICE, K. (1985) The development of scientific concepts through the use of interactive exhibits in a museum. *Curator*, 28, 35–46.

FRIEDMAN, A. J. (1995) Learning moments. *Association of Science–Technology Centres Newsletter*, May/June, 7,9.

GASKELL, G., WRIGHT, D., and O'MUIRCHEARTAIGH, C. (1993) Measuring scientific interest: the effect of knowledge questions on interest ratings. *Public Understanding of Science*, 2, 39–57.

GILBERT, J. K., and STOCKLMAYER, S. (2001) The design of interactive exhibits to promote the making of meaning. *Museum Management and Curatorship*, 19, 41–50.

GREGORY, J., and MILLER, S. (1998) *Science in public: communication, culture and credibility*. New York: Plenum Press

HARDING, S. (1991) *Whose science? Whose knowledge?* Milton Keynes; Open University Press.

HEIN, G. (1998) *Learning in the museum*. London: Routledge.

HIRSCH, E. D. (1987) *Cultural literacy: what every American needs to know*. Boston, MA: Houghton Mifflin.

HOUSE OF LORDS (2000) *Report of the Select Committee on Science and Society*. London: House of Lords.

HULL, G., and SCHULTZ, K. (2001) Literacy and learning out of school: a review of theory and research. *Review of Educational Research*, 71, 575–611.

IRWIN, A, and WYNNE, B. (1996) *Misunderstanding Science? The public reconstruction of science and technology*. Cambridge: Cambridge University Press.

KEEN, M. (1997) Catalysts for change: the emerging role of participatory research in land management. *The Environmentalist*, 17, 87–96.

KEEN, M., and STOCKLMAYER, S. (1999) Science communication: the evolving role of rural industry research and development corporations, *Australian Journal of Environmental Management*, 6, 196–206.

KRAUS, A. (2000) Insider information: the emergence of the corporate museum. *Museum News*, 79, 40–45, 66, 68–70.

LAYTON, D., JENKINS, E., MACGILL, S., and Davey, A. (1993) *Inarticulate science? Perspectives on the public understanding of science and some implications for science education*. Nafferton, UK: Studies in Education Ltd.

LUCAS, A. M. (1983) Scientific literacy and informal learning. *Studies in Science Education*, 10, 1–36.

LUCAS, A. M. (1991) 'Info-tainment' and informal sources for learning in science. *International Journal of Science Education*, 13, 495–504.

McKeown, K. C. (1952) *Australian spiders*. Sydney: Angus and Robertson, Sirius Books.
McManus, P. M. (1992) Topics in museums and science education. *Studies in Science Education*, 20, 157–182.
McManus, P. M. (1994) Families in museums. In R. Miles & L. Zavala (Eds.), *Towards the museum of the future: new European perspectives* (pp. 81–97). London: Routledge.
Melton, A. W., Feldman, N. G., and Mason, C. W. (1936) *Experimental studies of the education of children in a museum of science*. Washington, DC: Publications of the American Association of Museums.
Millar, R. (1996) Towards a science curriculum for public understanding of science. *School Science Review*, 77, 7–18.
Muscat, A. M. (2001) A practitioner's view on the value of an infra-structure for free-choice science learning. In J. H. Falk (Ed.), *Free-choice science education: how we learn science outside of school* (pp. 119–204). New York: Teachers College Press.
Office of Science and Technology and the Wellcome Trust (2001) Science and the public: a review of science communication and public attitudes toward science in Britain. *Public Understanding of Science*, 10, 315–330.
Pearce, P. L., and Moscardo, G. (1985) Visitor evaluation: an appraisal of goals and techniques. *Evaluation Review*, 9, 281–306.
Pedretti, E. (2002) T. Kuhn meets T. Rex: critical conversations and new directions in science centres and sciecne museums. *Studies in Science Education*, 37, 1–42.
Ramey-Gassert, L. (1997) Learning science beyond the classroom. *The Elementary School Journal*, 97, 433–450.
Rennie, L. J. (2001) Communicating science through interactive science centres: a research perspective. In S. Stocklmayer, M. Gore, & C. Bryant (Eds.), *Science communication in theory and practice* (pp. 107–121). Dordrecht: Kluwer Academic Publishers.
Rennie, L. J., Feher, E., Dierking, L. D., and Falk, J. H. (2003) Towards an agenda for advancing research on science learning in out-of-school settings. *Journal of Research in Science Teaching*, 40, 112–120.
Rennie, L. J., and McClafferty, T. P. (1995) Using visits to interactive science and technology centers, museums, aquaria, and zoos to promote learning in science. *Journal of Science Teacher Education*, 6, 175–185.
Rennie, L. J., and McClafferty, T. P. (1996) Science centres and science learning. *Studies in Science Education*, 27, 53–98.
Roschelle, J. (1995) Learning in interactive environments: prior knowledge and new experience. In J. H. Falk & L. D. Dierking (Eds.), *Public institutions for personal learning: establishing a research agenda* (pp. 37–51). Washington, DC: American Association of Museums.
SCAN (1998) The newsletter of the British Association for the Advancement of Science, November.
Schauble, L., Leinhardt, G., and Martin, L. (1997) A framework for organizing a cumulative research agenda in informal learning contexts. *Journal of Museum Education*, 22, 3–8.
Screven, C. G. (1984) Educational evaluation and research in museums and public exhibits: a bibliography. *Curator*, 27, 147–165.
Sjøberg, S. (2002) Science and technology education in Europe: current challenges and possible solutions. *Connect (UNESCO International Science, Technology and Environmental Education Newsletter), XXVII*, 1–5.
Sless, D., and Shrensky, R. (2001) Conversations in a landscape of science and magic: thinking about science communication. In C. Bryant, M. Gore, & S. Stocklmayer (Eds.), *Science communication in theory and practice* (pp. 97–105) Dordrecht: Kluwer International.
Stocklmayer, S. M., and Gilbert, J. K. (2002) New experiences and old knowledge: towards a model for the public awareness of science. *International Journal of Science Education*, 24, 835–858.
The Guardian Online (2002) *Lorenzo's trial* [http://www.guardian.co.uk/health/story/0%2C3605%2C812007%2C00.html], accessed 15 October 2002.
Thomas, G., and Durant, J. (1987) Why should we promote the public understanding of science? *Scientific Literacy Papers*, 1, 1–14.
Trefil, J. (1993) *1001 things everyone should know about science*. London: Cassell.
Wynne, B. (1993) Public uptake of science: a case for institutional reflexivity. *Public Understanding of Science*, 2, 321–337.