Science Communication: Towards a Proper Emphasis on the Social Aspects of Science and Technology

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Resumo. As fraquezas na educação compulsória são sumarizadas e usadas para explicar a continuação, em níveis inferiores aos desejados, de cursos pós-compulsórios e a falta de interesse em assuntos científicos pela população em geral. Tendo como pano de fundo um modelo de "comunicação científica interativa" que leva em conta tais fraquezas e que tem como foco central o tema dos "aspectos sociais da ciência/tecnologia", dois enfoques para melhorias são apresentados. O primeiro é o uso de cursos "baseados no contexto" dentro da provisão formal. O segundo é o uso muito maior de provisão informal, como museus, zoológicos e jardins botânicos, TV, internet, jornais e revistas, livros. Os desafios a serem enfrentados no uso destes dois enfoques amplos, nomeadamente: a natureza da ciência, da tecnologia, e a relação entre ambos; o tratamento do risco; o tratamento de assuntos contemporâneos, são avaliados. Por fim, maneiras de se conseguir as mudanças desejadas são sumarizadas.
Abstract. The weaknesses in compulsory school science education are summarized and used to explain the lower-than-desired uptake of post-compulsory courses and the lack of interest in matters scientific by the general public. Against the background of a model for 'interactive science communication' which addresses these weaknesses and which focuses on the key theme of 'the social aspects of science /technology', two approaches to improved provision are presented. The first is the use of 'context-based' courses within formal provision. The second is the much greater use of informal provision, namely that made through museums zoos and botanical gardens, TV, the internet., newspapers and magazines, books. The challenges to be faced in using these two broad approaches, namely: the nature of science, of technology, and the relation between them; the treatment of risk; the treatment of contemporary issues, are evaluated. Finally, ways to bring about these desirable changes are summarised.
Palavras-chave: comunicação científica interativa, curso contextualizados, mídia
Key words: interactive science communication, context-based courses, media

Current weaknesses in school science education

Many, if not all, countries requiring a statutory period of secondary school education have introduced a mandatory curriculum in 'Science'. This does lead to all younger students learning some science, however reluctantly. However, one consequence of this compulsion seems to be that, when they are given a choice of subjects for post-compulsory (pre-university) education, too few of them – in the opinions of their governments – choose the sciences. This is certainly the case, for example, in Australia (DEKKERS & DE LAETER, 2001), UK (ROBERTS, 2002), and the USA (BOARD, 2006).

Major subject-related reasons for this lack of persistence with the study of the sciences are dissatisfaction with the content of what is taught and how it is taught, a view which has been supported, to use the same examples, in respect of Australia (GOODRUM, HACKLING, & RENNIE, 2001), UK (OSBORNE & COLLINS, 2000), and the USA (HURD, 1994). The structural reasons for this disenchantment seem to be that the science curriculum: does not relate to the scientific ideas met outside school; does not sustain young people's sense of curiosity about the natural world; appears to the students to be a catalogue of facts; involves assessment that is too dependent on factual recall; separates science and technology; offers little scope for discussion and non-lecture teaching and learning experiences, and, perhaps most importantly of all, lacks a clear set of aims (MILLAR & OSBORNE, 2000).

There are two systems for looking at the objectives that underlie the science curriculum. The first, due to Roberts (ROBERTS & OSTMAN, 1998), classifies these goals on the basis of what knowledge, skill, or ability, they address. The second scheme (AIKENHEAD, 2006; FENSHAN, 2000) classifies them in terms of the political intentions of their originators. The Roberts scheme identified seven 'curriculum emphases'. These are present, to some extent, in all school science curricula and can be placed into two groups: Group A is concerned with those thought to be needed to perpetuate science as an academic pursuit, to ensure a steady stream of new scientists. It consists of:

* 'Scientific skill development'. This is concerned with the processes of developing scientific knowledge, these treated as involved the acquisition and use of a series of de-contextualised skills.

* 'Solid foundation'. This is the cumulative acquisition of propositional knowledge as a precursor to the further learning of science.

These two emphases have been collectively called 'wish-they-knew science' because the 'scientific establishment' believes them to be vital to the future of science as an activity (AIKENHEAD, 2006; FENSHAN, 2000).

Group B contains five emphases and is concerned with the 'the student functioning as a person, citizen, and employee':

* 'Structure of science'. This involves understanding how science functions as an intellectual enterprise i.e. how scientific knowledge is validated. This emphasis should also be placed in Group A, but it does seem to be generally neglected in both school and university science courses

* 'Correct explanations'. These are the conclusions so far reached by science needed for the citizen to understand how the world-as-experienced mechanically works. This is otherwise called 'need-to-know science' (AIKENHEAD, 2006)

* ‘Everyday coping’. Doing so involves making sense of objects and events of obvious everyday importance. This would certainly be included in ‘need-to-know science’ and also be relevant to ‘functional science’, the latter being of importance to people in science-based occupations (AIKENHEAD, 2006)

* ‘Self-as-explainer’. This involves the process by which of scientific explanations are produced. It entails a consideration of what influences people’s approach to explaining things and events and of the way that process functions. This would be of importance to those who deal with ‘have-cause-to-know science’, that is experts who deal with the general public on day-to-day issues (AIKENHEAD, 2006)

* ‘Science, technology, and decisions’. This emphasis is concerned with the way that scientific knowledge is reflected in technological innovations and with the social, political, and economic decisions that such innovations entail. This emphasis would also be part of ‘have-cause-to-know science’ (AIKENHEAD, 2006).

Two emphases fall within Group B and were not included in Robert’s taxonomy. One is ‘enticed-to-know science’, which is of interest to those who work in the media and who have to attract the public’s notice. ‘Personal curiosity science’ - that wanted by students themselves– is the second, and perhaps most educationally significant, omission (AIKENHEAD, 2006).

It does seem that the present dissatisfaction with school science stems from an historical tradition of an almost exclusive focus on the Group A emphases in the design of curricula.

The drive for science literacy

Faced with this decline in interest in science by school-age students, which has a roll-on effect on higher education admissions, on the job market, and on the conduct of scientific research, the educational agencies in individual countries have begun to initiate strands of reform, each of which entail a close consideration of the social element in and of science. This social element is concerned with meeting the very diverse and complex scientific needs of individuals, with meeting the more overtly social needs of the individual concerning science in society, and in showing how the conduct of scientific enquiry and the validation of scientific knowledge are social enterprises such that the conclusions reached are accepted as being true (at least for the time being!).

A first approach to reform is manifest in the slogan of 'scientific literacy for all'. Whilst many interpretations of 'scientific literacy' exist (DE BOER, 2000; LAUGKSCH, 2000), a widely used definition is:

'Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity' (N.R.C., 1996)(p.24)

In short, if 'scientific literacy' is to be the guiding metaphor for science education, Group B emphases, with their strong 'social' elements will, in the future, play a much greater part in the construction of curricula than in the past.

A second approach to reform, perhaps made necessary by the adoption of the first approach, has been a gradual change in the notion of 'science communication' that underlies science education. The traditional approach, that had resonance with 'behaviourist' models of the learning, was the 'sender-transmitter-receiver' model based on an analogy to the passage of an electrical current in engineering (DORMAN, 1990) (see Figure 1)

Transmitter
Sender ----------------------------- Receiver
(mediator)

Figure 1: The Sender-Transmitter –Receiver model

In this model, the 'message' is produced by the 'sender' (a scientist). This is 'transmitted' without any change in its nature by a 'mediator' (a school teacher and / or textbook) to the 'receiver' (the student) who learns the 'message' in unchanged form. The problems with this model are self-evident. The 'scientist' is rarely directly involved in producing the 'message', the latter being a simplified and often distorted version produced by the teacher /textbook (JUSTI & GILBERT, 1999). The message is passed one-way only (from 'sender' to 'receiver'), with the 'receiver' have no say in the nature of the 'message'. Only teachers /textbooks are involved in the 'transmission' process. The existence of a vast misconceptions /alternative conceptions literature stretching back over many years e.g.(GILBERT & WATTS, 1983) attests to the 'distortion in the received message'. This model is gradually being replaced by the 'interactive model' (LUHMANN, 1990)(see Figure 2) which has been heavily influenced by 'constructivist' theories of learning (OSBORNE, 1996).

Scientist $\Longleftrightarrow$ Mediator $\Longleftrightarrow$ Learner

Figure 2: The 'interactive' model of science communication

In the interactive model, the scientist provides information to the mediator (teachers, textbook authors, and as we shall see, other agents) in the light of the latter's needs and interests, there being a feedback process of expectation in operation. The mediator in turn composes a message, based on the interpretation of what has been received, in the light of perceptions of the needs and interests of the learner, there also being feedback from the learner. Lastly, the learner is seen as being able to express needs and interests, as well as preconceptions about the topic in question. In an ideal world, this model would be triangular, but the ratio of learners to scientists is always too high for this to be feasible.

A third approach to reform has been the gradual broadening of the school science curriculum from being solely concerned with 'science' to include 'technology': this also seems implicit in the notion of 'scientific literacy'. If science can be seen to be the seeking of predictive explanations for phenomena in the natural world, then technology may be defined as seeking to provide solutions to human problems. The design, production, and the use of technologies – the resulting solutions -all have social dimensions (PACEY, 1983). Indeed, the relationship between science and technology also has a social dimensional aspect based on the operation of 'cause and effect', for four models of the relationship exist (GARDNER, 1994, 1995). They are that: technology precedes science (e.g. the production of steel preceded the understanding of the impact of granular size on the strength of metals); that science precedes technology (e.g. the discovery of penicillin preceded its use in medicine); that science and technology are independent of each other (e.g. the evolution of 'radar' during World War 2 and the exploration of the properties of short-wavelength electromagnetic radiation); that science and technology interact as they evolve (e.g. the nature of genes are currently being discovered hand-in-hand with the anticipation of their use in medical technologies).

This emphasis on the social aspects of science and technology is most apparent in the implicit requirements to discuss: the nature of science and technology and the interactions between them; the notion of 'risk' as associated with science /technology; contemporary issues in science /technology.

The treatment of the nature of science/technology and the interactions involved

An understanding of a consensus view of the nature of science involves an appreciation that:

'* scientific knowledge, while durable, has a tentative character;
* scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and scepticism;
* there is no one-way to do science---;
* laws and theories serve different roles in science, therefore students should note that theories do not become laws---;
* peoples from all cultures contribute to science;
* new knowledge must be reported clearly and openly;
* scientists require accurate record keeping, peer review and replicability;
* observations are theory-laden;
* scientists are creative;
* the history of science reveals both an evolutionary and revolutionary character;
* science is (embedded in) social and cultural traditions;
* science and technology impact (upon) each other;
* scientific ideas are affected by their social and historical milieu'.
(adapted from: (MCCOMAS, CLOUGH & ALMAZROA, 2000)(p. 6-7)

An understanding of the nature of technology involves an appreciation that it consists of three elements: the technical; the organisational; the cultural (PACEY, 1983). Taking each in turn:

* the technical aspect is concerned with: knowledge (especially scientific knowledge); skills (being able to implement the design cycle –needs identification, design of solution, production of solution, evaluation of solution); outcomes (identification of the intended and unintended consequences of the use of the product);

* the organizational aspect is concerned with: economics (the balance of investment and return); sociology (the pattern of consumer decisions over the outcome); psychology (the basis of decision-taking by potential consumers);
* the cultural aspect is concerned with: the nature of the outcome in the context of its implicit cultural values; the view of creativity that inspired the outcome; the notion of social progress that underpinned the decision to seek the eventual outcome.

The notions of 'individuals acting scientifically on their own behalf', 'individuals acting scientifically in groups', 'groups acting scientifically in a broader society', and 'societies acting scientifically at global level' all permeate these requirements. What constrains the attainment of these understandings? The first of these is the notion of the 'nature of knowledge' held within any community. Moshman identified three stages from childhood through which this notion develops in individuals: the 'objectivist stage', where knowledge is seen as absolute and unproblematic; the ' subjectivist stage , where knowledge is seen to be uncertain, ambiguous, contextually-bound, and subjective; the 'relationist' stage where some forms of knowledge are more valuable than others (MOSHMAN, 1998)(p.694-5). It is not clear whether all individuals pass through all the stages: certainly, in any society there will be people with each of these beliefs. Only those people in the last stage would be able to accept the 'nature of science/technology' set out above as being one of the best, if not the best, way of acquiring knowledge about the natural world.

The second constraint follows on from the first. It stems from the existence in society of the phenomenon of 'pseudo-science' which can be defined as: the making of claims to knowledge about the natural world presented so that they appear to be scientific even though they lack supporting evidence. This phenomenon is worldwide and is manifest in many ways. For example, a survey of a large sample in the USA showed that in 2005: 42% of those surveyed believed in extra-sensory perception; 32% believed that houses can be haunted; 32% believed in ghosts; 31% believed in telepathy; 25% believed in astrology and in clairvoyance (MOORE, 2005). Examples abound: the reader is invited to type in 'magnetic water' (which is scientific nonsense) into a search engine. Those people in Moshman's 'subjectivist' stage would see such knowledge to be as equally valuable as that produced by genuine science, whilst it is quite possible that those in the 'relationist' stage might – perish the thought - see it to be superior!

What can be done to bring people to appreciate the nature of science /technology? In the context of the formal curriculum, (ABD-EL-KHALICK & LEDERMAN, 2000) came to the conclusion that a mixture of direct instruction and the discussion of the nature of science / technology during the conduct of laboratory enquiries was the most effective approach. (WANDERSEE, 2002) pioneered the use of 'historical vignettes' to do so: the use of scripted episodes from the history of science to support further research and the production of docudramas by university students. How these approaches might map on to informal provision has apparently yet to be explored.

The treatment of risk

'Risk' is a complex issue: seven different categories of definition of it have been identified (RENN, 1992)(p.57). However, for the purposes of discussing science communication, three simple definitions will suffice. The first is that risk is an expression of the probability that something unpleasant will happen. The second is that it is something that may happen and which should be avoided. The third is that a risk is something to be feared, dreaded, it is a threat to one's quality of life, indeed to that life itself. Why is 'risk' of importance when addressing the social aspects of science and technology? It is because those aspects involve the taking of decisions by individuals, groups, societies, all of which entail, to some degree, the acceptance of a degree of risk in respect of their consequences. Such decisions may have one or more of four types of consequence. There may be direct implications for the personal, social, or economic, life of individuals, for example, a decision to adopt a particular diet. The maintenance of public order may depend on such decisions, for example, the decision, which can lead to public demonstrations, to locate a nuclear power station in a given location. The social acceptance of new technologies will depend on the accumulated effect of decisions taken by myriad individuals e.g. to move away from reliance on petroleum-driven forms of transport. Lastly, and of greatest significance for the community of scientists /technologists, social decisions about the direction and degree of public funding of new initiatives are increasingly taken in democratic, or quasi-democratic, ways.

The problem about such decisions is that the different 'stakeholders' to any science communication undertaken with the 'interactive model' see 'risk' in one or more of the different ways summarised above. The science community see 'risk' in terms of the first definition: as a mathematical probability . Thus, what they attempt to communicate too often involves: an assumption of the meaning of any probability; the assumption of a precise understand of the formal definitions of the concepts used in the communication; the setting of the communication in a carefully defined physical context which may be different from that relevant or familiar to the general public; a limited vision of the personal and social implications of the knowledge being imparted; giving the impression that the relation of cause and effect between knowledge and its consequences is more deterministic than is the actual case. The 'mediator community' (e.g. journalists, television producers), because of the constraints of time and the need to attract an audience, tends to: place an often undue emphasis on an 'outrage' interpretation of any risks; fail to make those comparisons to other situations that would allow the evaluation of a risk by analogy to other risks of known consequence to take place. The public, including schoolchildren: generally lacks those mathematical skills needed to understand the scientific meaning of risk (Von ROTEN, 2006); tend to place an over-estimate on the magnitude of visible / sensory risks; show a greater tolerance of those risks that they believe to be under their personal control; show a lower tolerance of risks affecting many people; have a graduation of trust in 'authorities' when evaluating a risk (e.g. university staff are valued more highly than industrial scientists); tend to form 'social views' on any particular risk, a particular 'hazard' often being amplified (e.g. the controversy in the UK over the single-shot measles-mumps-rubella vaccine). Faced with this spectrum of the evaluation of any risk, governments tend to adopt the 'Precautionary Principle': they take action to prevent possible harm to individuals and groups when there is a level of scientific uncertainty over the risks involved in a decision or action. (e.g the limitations placed in the UK on the commercial cultivation of genetically-modified plants for foodstuffs).

There are some general ways in which the communication of risk can be improved. Scientists can be educated to show greater empathy for the concerns of mediators and the public by considering the broader contexts to which their work applies. Mediators can be encouraged to include accounts of the consequences of relevant known comparable risks in their reports whist, at the same time, taking care in regard to the treatment of 'hazard' and potential 'outrage'. The understanding of risk by the public could be improved by improving the general treatment of 'probability' in 'public service' educational activities. There is no doubt that that greater opportunities to question both scientists and mediators would enable individual members of the public to clarify their understand of specific risks. The widespread advent of phone-in and email facilities attached to media outlets (e.g. TV programmes) is bringing this about. The core issue is, of course, the capacity of all individuals to reach considered decisions. As Jarman & McClune

(2007) have pointed out (p.121), ‘decision-taking’ activities in school science are likely to be of limited impact because the activities cannot be comparable to the complex situations of everyday life. However, they believe that explicit instruction on decision-taking is needed.

A potentially useful approach to teaching schoolchildren to take decisions about particular risks is to have them use a checklist to individually evaluate a particular media report prior to a general discussion of the views reached. Such a checklist is (H.M.G., 1998):

* Are the aims of the communication clear?
* what are they?
* how do different stakeholders perceive the issue?
* what relation does the message have to previous messages?
* who was involved in producing the message?
* how and when were the stakeholders consulted?
* how are risk issues being addressed?
* how does the message relate to the likely values of the intended audience?
* if relative risks are given, is the baseline included?
* are any risk comparisons given helpful?
* how accessible is the language used likely to be to the intended audience?
* how is the reception of the message to be monitored?
* how is any data from that monitoring to be used?
* how are any general conclusions in the communication to be monitored?

The use of such a checklist across a range of science communications that include different forms of expression of risk could be very educational whilst being readily implemented.

The treatment of contemporary issues

At any time, those aspects of science and technology which are *contemporary* are almost always *controversial.* Teaching about such issues must, in the view of (OULTON, DILLON, & GRACE, 2004), emphasise that:

1. Groups within society hold differing views about them.
2. Groups base their views on either different sets of information or they interpret the same information in different ways.

3. The interpretations may occur because of the different ways that individuals or groups understand or 'see' the world (their worldview)
4. Different worldviews can occur because the individuals adhere to different value systems.
5. Controversial issues cannot always be recourse to reason, logic or experiment.
6. Controversial issues may be resolved as more information becomes available. (p.412)

Given the possible existence of tenaciously-held world views, education about controversial issues has to be based explicitly on a basic moral framework to which all can subscribe. (LEVINSON & REISS, 2003)(p.28) suggest an assumption of the equal treatment for all individuals with a consideration of the interests of those individuals as being capable of providing such a framework.

Oulton, Day, Dillon, & Grace (2004) suggest that the teaching of controversial issues should contain the following elements: a considerable emphasis on discussion by the students; the use of role play; the use of a wide range of resources, especially those involving an element of research (p.497). However, there is evidence that many science teachers find controversial issues difficult to engage with in class, for several reasons: the tradition of teaching science as a set of incontrovertible truths, of 'sticking to the facts'; the anxieties associated with the possibility that different worldviews are held by the teacher, the school as an institution, and the several communities from which students are drawn; the difficulty in ensuring that a full range of opinions are accessed by the students; the lack of any clear model for the progression of teaching of such issues across the span of compulsory schooling; the sheer amount of time that such work will absorb, in the face of a very heavy curriculum load (p.498). It is not surprising that the teaching of controversial issues is only very slowly gaining acceptance in school science teaching.

Providing a proper emphasis on the 'social' in science / technology education

The trends towards curricula that facilitate the development of 'scientific literacy for all', the assumption that science communication is best based on the 'interactive' model, and the bringing together of 'science' and 'technology', are being manifest in a number of ways. One of them is the introduction of 'context-based' courses in formal science education. A second is a growing awareness of the role that informal learning can play in science education and both school level and in respect of the older population.

Context-based courses

Context-based courses are emerging at an increasing rate, with the greatest interest in the genre being perhaps found in the school subject of chemistry (BENNETT & LUBBEN, 2006; PILOT & BULTE, 2006a) where the extent of student disenchantment is the greatest This pace of development, whilst welcome, is somewhat perplexing, given that:

--it does not seem possible at the present time to give a single, precise, technical definition of *context* ,and eventually we might have to accept that such a definition may not be possible. (DURANTI & GOODWIN, 1992)(p.2)

The notion of context that underpins any particular course must be such that the collection of contexts on which it is based: simplifies and /or reduces the content load of the curriculum by focusing on key ‘explanatory stories’ (MILLAR & OSBORNE, 2000); provides the basis for the development of a coherent mental map of the subject by the students; increases the likelihood that the conceptual understanding acquired can be transferred to other contexts; increases the interest of the students in the subject; and, most importantly in the present context (sic), must address the wide range of social issues associate with science /technology (GILBERT, 2006)(p.959).

A context that is educationally valuable must have four characteristics. It must provide a setting, especially a social setting, in which students may engage in mental encounters with events on which attention is focused. The environment in which these encounters take place must be one of genuine enquiry, reflecting as far as is possible the conditions in which scientists/ technologists operate. The environment must be such that the ‘ways of talking’ that are specific to the subject are developed by the students. Lastly, the prior knowledge of the subject, including alternative conceptions / misconceptions, must be used and their explanatory adequacy explored. (after: DURANTI & GOODWIN, 1992)

So, how closely does the current use of ‘context’ in ‘context-based’ courses meet these criteria? Four models of course have been identified (GILBERT, 2006)(p.966-971). In Model 1, one or more contexts is only referred to at the end of a sequence of traditional teaching of science concepts and then by way of the application of those ideas. Given that the core concepts will only be drawn from the lexicon of pure science, the social dimensions will get scant treatment. In

Model 2, the core concepts of science are taught whilst the students have before them exemplar situations (contexts) to which they apply. Again, the social dimensions are likely to be ignored unless they are reflected in the post-course assessment. In Model 3, the student is encouraged to relate the core concepts to the contexts as are the former are being taught. Given the broad interests of many students, this does mean that social issues will arise, if only as a result of students' questions. In Model 4, the context takes centre-stage, with the social issues being addressed on a par with the core science concepts. Alas, it does seem that, at present, the incidence of 'context-based' courses decreases from those based (however implicitly) on Model 1 (tokenism) to Model 4 (broad-based, genuine, enquiry). However, even this very partial use of the potential of context-based courses does seem to be yielding many positive outcomes. Bennett reported that: students' interest in and enjoyment of science lessons was increased when these were context-based; such courses enable students to see more links between science and their everyday lives; such courses are as effective as conventional approached to teaching core science concepts. However, there was little evidence that such courses encourage students to persist in the study of science (BENNETT, 2003). Pilot and Bulte (2006b) have outlined some of the challenges to be faced if the potential of context-based courses are to be more effectively addressed, leading to the introduction of more Model 4 courses.

Sources of informal learning of science and technology

To create a possible scenario, it is unlikely that a student of compulsory-school age has more than one hour of 'science' in a perhaps seven hour school day for forty weeks of the year: a total of two hundred hours of *formal* science education, of whatever quality, per annum. Assuming that twelve hours per day are spent on 'system maintenance' (eating, sleeping, etc), this leaves maybe at least 250 hours per annum into which some *informal* science education can be inserted. 'Formal ' science education is usually taken to mean that framed by the school curriculum, such that what is learnt, how it is learnt, and at what pace it is learnt, are not in the control of the individual. 'Informal' science education, which has also been called 'free choice' science education (FALK, 2001), is characterised at the opposite pole: the individual takes full control over what is learnt, how it is learnt, and when it is learnt. Such informal science education may be provided in a wide range of ways, of which some of the most significant are: museums, science centres, zoos, botanical gardens; television; the internet; newspapers and magazines; books. In between the two extremes lies *non-formal* science education, where the resources of informal provision are co-opted to support formal provision e.g. through a school-organised visit to a museum is conjunction with the study of a particular theme in the science curriculum.

Whilst a number of books have been published on ‘science communication’ in general e.g.(GREGORY & MILLER, 1998; STOCKLMAYER, GORE & BRYANT, 2001), only a few have focused on specific forms of provision in formal and informal provision, notably museums (BICKNELL & FARMELO, 1993; HOOPER-GREENHILL, 1991; PARIS, 2002), with even fewer on the role of a specific form in formal school science education alone e.g.(JARMAN & McCLUNE, 2007). It is not possible to consider each of the forms of provision in detail here, but their relative merits in respect of several broad criteria, each of great significance in respect of the social aspects of science, can be evaluated in summary. These criteria are:

* the capability to deal with the social aspects of the natures of science, technology, and the relationships between them
* the capability to deal with the social aspects of the issue of ‘risk’;
* the capability to discuss the social aspects of contemporary issues in science / technology so as to present all the relevant issues together with the associated evidence.

Taking the major forms of provision in turn:

Museums, zoos, botanical gardens

This group of forms of provision, taken in its pure ‘exhibition’ format, is limited in its ability to deal with the processes of science and technology because, whilst the latter involve the passage of time, the former are largely fixed in respect of their depiction of time. However, the group can readily deal with the mathematical aspects of ‘risk’ and to show, by means of pictures, something of the ‘hazards’ that particular calculations of risk entail. Similarly, they are well placed to deal with contemporary issues in science and technology. The genre can be made more flexible by including ‘interactive’ exhibits and by associating it with fixed-cycle video recordings. But how valuable is the contribution made to science communication by this group? The contribution in respect of ‘risk’ and ‘contemporary issues’ will depend on the ability of the design staff to respond to emerging issues at short notice, if the impact is to be significant. Moreover, whilst this group does attract a significant number of visitors in any country and in any year, those visitors do tend to be those who have strong general educational backgrounds.

Television

Almost every household in developed countries and every village in every Third World country today has a TV. The issue will be the choice of programmes to watch (that often being a very social matter!). Programmes that are oriented to those with a strong interest in science communication, for example *Horizon* in the UK, can do an excellent job in presenting the natures of science and technology because of their capacity to present experts and their ready use and juxtaposition of actual phenomena, models, and animations. Similar arguments apply to the treatment of 'risk' and 'contemporary issues'. The range of provision made will depend on the policies of the programme makers, not least because such programmes are expensive to make. Again, their uptake in the populations will be limited to those with a prior interest in science and technology, although those people who do view them will probably learn a great deal.

Internet

The growth in access to a computer, especially one with an internet connection, has been explosive in the past decade. It is difficult to estimate this quantitatively, even for individual countries. There is evidence of increasing use of the internet to acquire scientific information in order to meet immediate personal, social, and economic needs (SELWYN, GORARD, & FURLONG, 2006). The absence of any form of quality control in respect of the websites available will make great demands of the viewer in terms of selecting a particular website and in judging the status of the material contained there. The themes of provision made will depend on the whims of individual contributors, the motives of which are not open to inspection by the viewer or his / her surrogate nominee.

Newspapers and magazines

Whilst the treatment of the 'nature of science /technology' is probably largely the province of magazines, newspapers do lend themselves to the treatment of 'risk' and 'contemporary issues'. Certainly the treatment of 'contemporary issues' would be of appeal to the editors of newspapers, with their eyes forever on sales figures, although the 'balance' in the treatment given in a particular case would depend on the editorial policy, and image of 'audience', adopted. The range of provision made by the different newspapers in any one country is wide and, even when sales figures are known accurately, the effectiveness in providing 'science communication' is very difficult to gauge.

Books

These, by their very nature, are confined to the literate section of any population in any country: say a maximum of 80%. However, the range of types of books that deal, in one way or another, with science /technology, is great, ranging from ‘informed glossies’ (e.g. the spin-off from David Attenborough’s many wild-life series on TV), through the ‘crime novels’ (e.g. the spin-off from the widely watched CSI-Miami series on TV) to biographies of great scientists (e.g. of Leonardo Da Vinci) (WHITE, 2000). They are all well-suited to deal with the social issues of ‘nature of science/technology’, ‘risk’, ‘contemporary issues’.

What conclusions can be drawn from this inevitably sketchy treatment of the major forms of provision of science communication? The answer must be: very few, given the lack of ‘communication-effectiveness’ research that has been carried out on many forms e.g. books, internet. It does seem that those forms which can be produced quickly, which make extensive use of multiple images, which allow the audience to attend to the ideas involved for a substantial length of time, will be the most effective.

Bringing about change in the practice of science communication

How can changes be brought about so that more support is provided for the Group B emphases in science communication. Changing the formal science curriculum to make greater use of ‘context-based’ approaches will not be dealt with here: the general issues and approaches to their resolution have been dealt with elsewhere (BLACK & ATKIN, 1996).Attention will rather be focused on the greater provision of *informal* science communication and on the exploitation of these resources for *non-formal* science communication purposes. To do so, the (GOODLAD, 1979) and (Van Den AKKER, 1998) model for ‘curriculum representation’ will be adopted for broader ‘science communication representation’ purposes. Such a model has five ‘levels’ of representation:

* the *ideal* provision

This would consist of a statement of those goals of science communication that were concerned with ‘social’ issues. Doing so would entail collaborative work with those having strong interest in the subject. One major hindrance is the absence of any forum where such people can meet. The ‘science education’ conferences are focused on schools, with only very minor provision being made for ‘informal science education’. The ‘media’ conferences have a general orientation and are not concerned with cognitive and pedagogical issues. An international ‘watering hole’ for ‘science communicators’ is needed.

* the *formal* provision

This would state what kind of material and activities could best be presented through which form of provision. In order for this to be done, there needs to be much more detailed research into which form, or combination of forms, is best suited to what material /activities. Such judgements can only be safely arrived at by conducting enquiries into the reactions of the ‘receivers’, the ‘learners’ as, or immediately after, they have used materials/ activities. Such research will be demanding, not least to get the cooperation of potential interviewees, given that they would be under no compulsion to be helpful.

* the *perceived* provision

For it to actually be acted upon, the formal provision will have to be accepted, valued, and implemented, by the providers i.e. the ‘mediators’. The ‘mediators’, being a very diverse group, will give varying priorities to aspects of the formal provision, they will perceive what is required in different ways, dependent on their own sectarian skills and interests. Again, bringing this group together would be very helpful.

* the *experiential* provision

This would consist of a catalogue, however partial, of the materials /activities available, together with case studies of how individuals, drawn from different groups in the ‘public’ (including schoolchildren)(O.S.T., 2000), responded to those opportunities

* the *attained* provision

However desirable, it does seem very demanding of resources to identify what individuals have learnt from different forms of provision. Often people are not consciously aware that they have learned something, their memories being stirred by later events. However, the exception is the situation where a person deliberately seeks information (increasingly this is from the internet) in response to a perceived personal need, an approach that David Layton first commented on 20 years ago (LAYTON, DAVEY & JENKINS, 1986). More case studies of such investigations, the circumstances that led to them, and their consequences, would be very informative for the future development of science communication.

Conclusion

National educational systems seem to be increasingly prescriptive of what they demand that young people learn. At the same time, young people seem increasingly disinterested in what is provided, this being marked in respect of science. The school, as a vehicle for the transmission of a fixed body of scientific knowledge, seems to run the risk of having substantially outlived that part of its usefulness. However, the ever-increasing availability of informal means of science communication offers a major avenue for future development. It is the nature of this avenue that it lends itself more readily to the treatment of the 'social' aspects of science. These are at the forefront of the concerns of the public and of the future, rather than the past, of societies.

Whether attempted through formal, non-formal, or informal, means, the effectively of any address to the social aspects of science /technology will be manifest in the cognition of individuals. What will be looked for is a broader range of *attitudes*: the learned dispositions to respond in a consistent manner to allied objects, events, processes, or ideas. Those who perceive science /technology as primarily damaging the environment would come to see this balanced, to some degree, by the general improvement in human health and life-span over the past century or so. Such attitudes will be shown in a greater impact of science / technology on the *beliefs* that people show: the information that they hold to be both true and relevant about the attributes of objects, events, processes, or ideas. In particular, they may come to see the value of scientific methodology in acquiring such information. Armed with broader and more scientifically-informed attitudes and beliefs, individuals will go about their lives with altered *intentions*: the expectation that they would respond to new circumstances in a modified way. These reconsidered intentions might then lead to different *behaviour*: acting on the world-as-experienced in a way that may be different to what might have been expected had not the education taken place.

Changing attitudes, beliefs, intentions, and behaviours, in respect of science / technology is something that 'science communication' is only just coming to grips with. How can the challenge be approached? The idea of 'cognitive dissonance' is potentially very helpful (FESTINGER, 1957):

‘Cognitive dissonance is a psychologically unpleasant state that arises when an individual holds two beliefs about an object etc that are in conflict with one each other. This dissonance cane be reduced by changing one of the beliefs’

It should be noted that a person’s attitudes are not necessarily changed by exposure to such an experience: the original will continue to be adhered to if it serves personal purposes more effectively that the newcomer.

How might cognitive dissonance be engendered in practice in a science communication context? One way is to expose a person to a persuasive communication, in which the merits of an alternative interpretation are put forward coherently. The recent opening of a museum in the USA which advocates a ‘creationist’ interpretation of the appearance of life on Earth, in contrast to the Darwinian ‘evolutionist’ approach, is a recent example of an attempt to do this. Approaches that seem more likely to be effective in engendering cognitive dissonance place an emphasis on the participation of an individual in activities. Personal discussion with a person holding different views is believed to be effective. Causing a person to engage in role play, where they advocate ideas in which they do not believe, is a second approach. Such approaches are already in use in classrooms, but probably without the underpinning of why and how they could be effective.

Bringing about such changes in the purposes, the nature of provision, the teaching and learning methods adopted, may be traumatic for science communication as currently practiced. However, these changes will have to come about if the social aspects of science /technology are to be addressed, for such is requisite for the survival of science communication as an activity in which students engage with attention and enthusiasm.

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