The relationship between science and technology in the primary curriculum – alternative perspectives

RESEARCH

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Introduction

The removal of subject-content overlap in the National Curriculum for England and Wales under Sir Ron Dearing (DfEE 1995) may have drawn subject boundaries more firmly in the primary classroom, but the author believes that a special relationship can still be claimed for science and technology. Before going any further, there is an immediate need to clarify terms. Are we talking about information technology (IT) or design and technology? Whilst acknowledging the huge contribution that IT makes to scientific discovery I have chosen to restrict myself to a definition of 'technology' as 'design and technology' for the purposes of this article.

Several large questions remain. Are we talking about science and technology as they occur in the primary classroom, or a wider definition encompassing the 'real world out there'? The answer to this question is really "both" because it is the central thesis of this study that the way we see the relationship between science and technology 'out there' *fundamentally affects* the ways we choose to teach the subjects in the classroom. I will outline several categories of views of this relationship which could be taken, and their accompanying pedagogical implications.

Before embarking on this task it is worth noting that there is still significant room for interpretation in the meanings people give to the words 'science' and 'technology', which could at least go some way towards explaining the different views of the relationship between them. Science could be seen as a body of knowledge, a community of professionals, a set of processes to test and refine knowledge, or a combination of all three. Similarly 'technology' could mean technological artefacts, a system of know-how ("We have the technology...") or the study of what designers, engineers and technologists do. Are we talking about the ways in which scientific and technological knowledge overlap, the relationship between professional bodies, similarities between process skills used, or the ways in which scientists and technologists can help each other? For the purposes of this review I am largely confining myself to science and technology as *processes* undertaken by professionals, and as such I am looking at the extent to which those processes overlap, and whether scientists and technologists depend on one another's work for progress in their own fields.

Categorising views of the relationship

> "The relationship between science, technology and industrial success in modern societies is complex." (Wolpert 1992, p. 34)

The question of how science and technology affect one another is an old one. The question of the relationship between *theoria* and *techne* goes back at least as far as science itself, so it is unlikely that it will yield straightforward answers. If it did we would be left with one clear view of how science and technology interact, which as educationalists we could pick up and plan science and technology curricula accordingly. However Layton (1993) warns us against any such simplistic solution:

> "It is clear... that simplistic models of the relationship between technology and science must be rejected." (Layton 1993, p. 26)

The House of Commons Standing Committee on Education (1995) has acknowledged the difficulty of defining technology, and of defining it in relation to science. Nevertheless, the question is an important one for governments to consider, because in addition to the implications for what is taught in schools, official policy in this area has a radical impact on research funding and hence the types of science and technology which receive support in our society.

In considering the range of views on this subject it will be useful to have a framework into which we can categorise them. Such a framework has been suggested by Gardner (1994) who claims that for many people the phrase "science and technology" rolls off the tongue as a single, undifferentiated unit, with no attempt made to distinguish between them. This view of the two as *indistinguishable* stands in contrast to four other positions which treat science and technology as different:

"(i) Science precedes technology, i.e. technological capability grows out of scientific knowledge; this position, often called the *technology as applied science* (TAS) view, is widely held and influential.

(ii) Science and technology are independent, with differing goals, methods and outcomes (the *demarcationist* view).

(iii) Technology precedes science; this *materialist* view asserts that technology is historically and ontologically prior to science, that experience with tools, instruments and other artefacts is necessary for conceptual development.

(iv)Technology and science engage in two-way interaction; this *interactionist* view considers scientists and technologists as groups of people who learn from each other in mutually beneficial ways." (Gardner 1994, p. 5)

I will explore each of these views in turn, examining the support for, and criticism of each. I will also begin to examine the pedagogical implications of the various positions, to advance the thesis that the view we take of the relationship between science and technology will necessarily affect the way we teach them.

1. Science and technology as indistinguishable

Popular media tend to use the terms 'science and technology' interchangeably, or as one homogeneous phrase. Undoubtably the two are inextricably linked in the minds of some politicians, who talk about the country's 'science and technology base' as the engine for economic growth, hence providing an 'industrial trainers' (Williams, 1961) rationale for education in both fields. This view also has some support amongst academic scientists:

"...the room labelled Science is not sharply cut off from its neighbours but opens in every direction to less specific, less 'certain' apartments in the House of Intellect." (Ziman 1968, p. 40)

Ziman argues that, although in the past science and technology were distinguishable by their methods and outcome, their role in research and development within a modern technological society renders any hard and fast distinctions redundant:

"There was once a time when Science was academic and useless and Technology was a practical art, but now they are so interfused that one is not surprised that the multitude cannot tell them apart." (Ziman 1968, p. 24)

Hence modern technology can be seen as deliberately scientific in nature, and contemporary science is largely geared to technological ends, using technological means to achieve them. Lelas (1993) sees science as technology, claiming that the very act of experimenting is itself a form of technological innovation:

"Know-how is a legitimate, constitutive and indispensable part of scientific knowledge. Science is as genuinely technology as it is ontology... Scientists discover as they implement: implementation has a peculiar and important cognitive role." (Lelas 1993, p. 424)

Scientists' technological know-how is nowhere so important as in the act of *observation* which is, Lelas argues, not the detached, passive activity scientists would have us believe. When using technology to observe, the scientist is manipulating nature to reveal aspects which were not previously evident, thus shaping reality much as a technologist shapes materials when creating an artefact:

"Instrumentally aided observation mixes *theoria* with *techne*, vision with know-how, observation with engineering... The whole idea of experimentation is to investigate nature by putting it on trial...the experimenter does this by tricks or cunning interventions..." (Lelas 1993, p. 430)

Of course, designers and technologists observe things too, often with the aid of instrumentation. The purposes of this observation – to find out how things work, to see the effects of changes made – might be seen as very similar to those of the scientist looking at the 'workings of nature' or the effects of experiment. Further evidence, it could be claimed, for the indistinguishability of science and technology.

Implications for the curriculum of an 'indistinguishable' view

The logical consequence of such a view might be to propose a single subject area for the primary curriculum called 'science and technology', or to subsume both areas within an overall integrated topic work approach. Indeed, for several years before the National Curriculum, science and technology were often grouped under one heading, often that of 'problem-solving' (Engineering Council, 1985). The cross-curricular skills involved in problem-solving might, under this view, be seen as more important than the individual content of science or technology themselves:

> "The (problem solving) approach can be used to help children understand the man-made (sic) world through practical problem-solving, involving using and discovering scientific concepts and skills in conjunction with design-and-make activities." (Engineering Council, SCSST 1985, p. 13)

An undifferentiated approach of this type was even suggested by the National Curriculum Science Working Group in its early deliberations. This paragraph is taken from their interim report:

> "Technology and science are, and always have been, very closely interrelated at the primary level. Under the label 'science', children have been posing questions which they have answered by creating models of various kinds, testing them and improving them, tackling problems of control using mechanical and electrical devices, using ready-made and improvised means of measuring and of extending powers of observation, as well as testing ideas. The recognition that much of this is technology does not alter the nature of the work, but does require that we label it more accurately as 'science and technology'. Within this label we have not attempted to treat separately the interrelated scientific and technological aspects of learning; we use the phrase to mean the exploration of the world around us through investigation and interaction with the things in it in an attempt to understand, to frame questions and to use materials creatively in seeking solutions." (NCC 1987, para.. 95)

A far cry, it would seem, from the current widespread vilification of cross-curricular teaching and the 'topic approach'. The difficulty of 'teasing out' the strands of children's scientific and technological learning certainly arises, but for those who consider the two to be indistinguishable this is not an issue.

Criticisms of a view of science and technology as indistinguishable

Unsurprisingly, this view has come under criticism, not least by many scientists who feel that the nature of their discipline is under threat from such a 'watering down'. The modes of thinking required in science and technology, claims Wolpert (1992), are so fundamentally different that any attempt to blur the line between them is misleading and risks confusing the issue:

> "Much of modern technology is based on science, but this recent association obscures crucial difference, and the failure to distinguish between science and technology has played a major role in obscuring the nature of science." (Wolpert 1992, p. 25)

For a fuller examination of the principles which underpin such a criticism we need now to turn to what Gardner (1994) has described as the *demarcationist* view.

2. Science and technology as separate activities

Supporting a *demarcationist* perspective, Polanyi (1958) argues that scientific and technological modes of understanding are almost mutually exclusive, so that to understand the physical or chemical

RESEARCH

concepts implicit within a piece of technology is not necessarily to appreciate its operational principles, and vice-versa. A scientific analysis of, say, a mobile telephone would not tell us anything about its design significance as a 'cultural icon' or indeed how to make another one, hence "...the two kinds of knowledge, the technical and the scientific, largely by-pass each other." (Polanyi 1958, p. 331). Wolpert (1992) has concluded that scientific and technological modes of thought have 'clear water' between them, the latter drawing strongly on *visual imagery* and non-verbal expression, whilst scientific thought is largely expressed through *the symbolic language* of mathematics:

> "The very natures of scientific and technological thinking are dissimilar. Many aspects of technology are visual and non-verbal, which is quite unlike scientific thinking. It is not that scientists do not visualise structures, concepts and mechanisms, but exposition is fundamental to science and the images must be translated into language and symbols, particularly mathematics."
> (Wolpert 1992, p.34)

The purposes of science and technology, argues Wolpert, are also distinctly different. The purpose of science is to produce 'tested knowledge', whereas technology results in the production of usable objects, valued for their human and economic value rather than their contribution to knowledge. It can be argued that such a view is assuming a certain value position with regard to the status given to different forms of knowledge. Implicit within Wolpert's argument is a picture of science as independent and objective, describing external reality in nature independent of human culture, contrasting with technological knowledge which is accorded the low status of 'common sense'.

Implications for the curriculum of a demarcationist view

Clearly, a demarcationist would wish to see two separate schools subjects, with little or no overlap between them. There has been some movement in this direction in the recent revision of the National Curriculum for England and Wales (DFEE 1995) under the chairmanship of Sir Ron Dearing, which has had as one of its stated aims the 'de-duplication' of content between subjects. Accordingly, all mention of 'energy' has been removed from the science curriculum, being assigned to technology. This review has largely dealt with knowledge content, but there have also been changes in the process model for technology, moving it towards a two stage 'design and make' model, which has less in common with the process of scientific investigation as described within the science Programmes of Study than previously. Predating this assertion of the difference between the skills used in each subject, Sparkes (1987) proposed contrasting models of the scientific and design processes which emphasise the distinctiveness of each:

"Key Activities in Science	Corresponding activities in Technology
a) explanation and prediction	a) successful products
b) discovery	b) invention
c) theorising about causes	c) theorising about processes
d) analysis	d) design
e) reductionalism (ie. making distinctions, isolating phenomena by controlling experiments and removing unwanted environment if necessary)	e) holism (ie. bringing many different analyses bearing on design problems dealing with complexity and only controlling the influences)
f) search for causes	f) search for solutions
g) study and research for its own sake	g) study and research for pursuit of only as much accuracy as is necessary for success
h) reaching correct conclusions based on accurate data	h) reaching good decisions based on incomplete data"

(Sparkes 1987: 7)

From this list it could be concluded that, whilst scientists and technologists may undertake activities which appear superficially similar, the purposes for which they are undertaken are often completely different, and the criteria for success directly contradictory.

Criticisms of a demarcationist view

The portrayal of scientists and technologists as different 'breeds', claim its critics, does not stand up to close scrutiny. It demonstrably does not happen in the 'real world', where scientists and technologists are often engaged in the same research and development (R&D) projects:

> "The dichotomy between the 'scientist' who responds only to his own needs in the intellectual realm and the 'technologist' who responds only to the demands of others in the practical sphere, is totally false." (Ziman 1980, p. 100)

The objective, value-neutral nature of science implicit within the demarcationist view is also open to question, in a century where scientific knowledge is becoming less certain, and a cultural context in which scientists produce different findings depending on who funds them. To take such a view, claims Ziman (1980) is to absolve scientists of their social responsibility, leading to potential ecological disasters and widespread public alienation. In response to such a barrage of criticism, many demarcationists might adopt a 'fall back position' which does acknowledge some connection between scientific knowledge and technological application. In doing so, they would be moving towards the third of Gardner's (1994) categories: *Technology as Applied Science* (TAS).

3. Technology as applied science

The well known phrase used to advertise Zanussi domestic appliances – "the appliance of science" – sums up a popularly held belief that in order for science to be made useful, technologists need to take the knowledge generated by the scientific community and use it to address human needs. Well known examples quoted to support this view include the development of nuclear power following Einstein's postulate of nuclear fission and 'Teflon' (PTFE), the substance used to coat non-stick frying pans originally 'discovered' during the US space programme. This view has tended to pervade official science and technology policy, and has attracted some powerful proponents:

> "Many prominent advocates of increased recognition of applied science and technology have argued that the allegedly close ties between pure science and technological and industrial applications should be maintained or even strengthened. The Duke of Edinburgh continually emphasised the need for a fruitful alliance between science and technology." (McCulloch, Jenkins and Layton 1985, p. 210)

Within this view, there is (as with the demarcationists) an implied hierarchy of discipline, with science clearly taking precedence over, and possibly even subsuming, technology:

> "The notion that the scientific culture as a whole embraces applied science and technology may be taken to imply that scientific principles provide an essential base for technological applications." (McCulloch, Jenkins and Layton 1985, p.18)

Thus science is seen as of vital importance to the economy, provided that the research which attracts funding is clearly directed towards industrial goals, rather than the abstract pursuit of 'truth':

> "...the deliberate *planning* of research on particular topics, with the expectation of arriving at results with preconceived applications, is a characteristic of modern society." (Ziman 1980, p. 91)

Such a view might result, in policy terms, in a shift away from funding 'basic science' in favour of a more 'strategic' approach, geared to the needs of industry.

Implications for the curriculum of the TAS view

A science and technology curriculum constructed on such principles would definitely place a greater emphasis on science, but within an 'industrial trainers' rationale (Williams, 1961), such that children would study science and its applications in order to contribute to the national economy at some later date. This view of science education has become increasingly prevalent in the last twenty years:

> "The theme which became increasingly dominant in the 'Great Debate' after 1976 was the persistent problem of how to relate education, and particularly school science, more closely to the needs of society and industry." (McCulloch, Jenkins and Layton 1985, p. 191)

Secondary school science teachers have often been wary of technology studies, fearing an erosion of their position within the curriculum hierarchy, and preferring to entrench by covering any technological applications within a subject called 'applied science':

> "A position strongly argued by some science educators was that the introduction of technology as a separate field of study should be opposed; it would lead to science education becoming more pure because the applications of science would be dealt with in technology... Technology, then, was to remain subservient to science, assimilated into science education for the benefit of the latter, with the main road to pupils' technological understanding and capability being through science." (Layton 1993, p. 19)

If design and technology is to be included as a distinct area within such a curriculum, the most likely way of combining it with science studies would be to teach the science first, then apply the concepts developed in science lessons in a design and technology project. For example, the teacher might introduce simple circuits through a science investigation on switches, then ask the children to design a torch. The implication within this model is that science takes the lead role, with design and technology gleaning 'scraps of scientific wisdom from the master's table'. The irony is that despite few educationalists subscribing wholeheartedly to the *TAS* view, much of science and technology education is actually constructed on this basis:

> "Hardly anyone now thinks of technology as merely applied science, but, in practice, many people treat technology studies as applied science studies. The assumption behind this strategy is that there are sufficient similarities between science and technology that models developed in science studies may usefully be applied in technology studies." (Giere 1993, p. 103)

Because science has a longer history as a school subject, and is still widely regarded as more academic than technology, this state of affairs has been allowed to persist. The view found expression in one of the redrafts of the National Curriculum Order for technology (1993) in which greater emphasis was given to structures and mechanisms at the expense of generic design skills. This change proved to be a source of anxiety for many primary teachers.

Criticisms of a view of technology as applied science

One of the principal criticisms of this view is that it is too simplistic, and does not match reality in most cases. Scientific knowledge often needs to be considerably reworked (Layton 1990) to make it useful in the highly complex 'real world' of technology with its multitudinous human and economic factors. As Black (1995), Wolpert (1992) and others point out, history is littered with technological advances which took little or no account of science, and inappropriate applications of scientific knowledge which proved disastrous because of lack of understanding of the human context of the technology. The accompanying view of science as objective and value-free has thus been imposed on technology to the impoverishment of both disciplines:

> "If one were simply to apply an enlightenment rationalist picture of science to the study of technology, one would miss most of what are now

regarded as essential features of modern technology." (Giere, 1993, p. 104)

One consequence for the curriculum of such an approach is that there is a risk of undervaluing design skills (Gardner 1994), and sending messages to children that scientific knowledge is more important than technological capability in gaining access to technological careers. The other main objection from a designer's point of view is that science is not the only source of knowledge upon which they need to draw, a point acknowledged by the Design and Technology Working Group in their interim report:

> "One position, strongly advocated by some experienced professional designers, is that the body of knowledge in support of design is unbounded; designers have the right and duty to draw upon knowledge from whatever sources seem likely to assist them in their quest for a solution. In contrast, if we look at the prevailing orthodoxy in much secondary school teaching of subjects related to design and technology, we find an emphasis on relatively narrow veins of knowledge concerned with topics such as materials, mechanisms, structures, energy and electronics." (NCC 1988, paras 1.24, 1.25)

The very question of whether children are able to transfer knowledge from science lessons to design and technology activities has been called into question. Research (McCormick and Murphy 1994) has found little ability in children to use knowledge gained in one context to another:

> "...assuming that learners can access and apply relevant bodies of knowledge from other contexts is unrealistic. Pupils frequently appeared not to have grasped concepts in such a way as to enable them to *use* them in a practical situation." (McCormick and Murphy, 1994, p. 10)

Indeed, the evidence from the work of many developmental psychologists (Piaget, Bruner, Donaldson etc) would suggest that transfer of concepts from the practical to the theoretical (rather than the reverse implied in the TAS model) matches more closely the way in which children learn. Could it also be that science has derived many of its abstract constructs from practical experience of technology?

4. Science as dependent on technology (a materialist view)

This view is often supported from an historical perspective: the human activity of technology (designing and making things) is very much older than that of science, and many fundamental advances (the wheel, agriculture etc.) were developed without reference to abstract, generalised theories:

> "Not until the nineteenth century did science have an impact on technology. In human evolution the ability to make tools, and so control the environment, was a great advantage, but the ability to do science was almost entirely irrelevant." (Wolpert, 1992, p. 25)

Although technology did not need science for most of its history, Wolpert argues, "science by contrast has always been heavily dependent on the available technology, both for ideas and for apparatus." (op. cit., p. 30). It is certainly possible that by observing the intricate mechanisms of advancing technology scientists of the Enlightenment built up their picture of a 'clockwork universe' with every part having a precise, predetermined role to play. And how would Galileo have developed a model of the solar system without a telescope with which to observe the moons of Jupiter? However it is not only historically that technology can be seen as taking precedence over science. It is also much more important economically; the ability to invest in innovation is vital for economic success:

> "Economic success has become associated more with technology than with pure science. It is argued that despite producing more Nobel Prize winners in physics and chemistry per thousand of population than any other country, Britain's economy is still not competing effectively." (Layton 1993, p. 24)

Scientists are highly dependent on the products of technology – computers, scanners, particle accelerators etc. – for their work. They do, of course, make some contribution back to the development of new technology, but this is very much in a background or peripheral role according to proponents of this view:

> "...science is far from irrelevant, although its role is often a supporting rather than an initiating one. For example, it offers techniques and advice which can be critically important in the successful development of a technological innovation." (Layton, 1993, p. 25)

Such a position clearly casts technology as the lead discipline, demoting science from the pedestal upon which the demarcationists and TAS proponents have placed it. Such a shift has far-reaching implications for education.

Implications for the curriculum of a materialist view

An approach favoured by design and technology specialists is to use some scientific knowledge or skills where they might profitably help a technology project. For example, a short investigation into the insulating properties of various materials would be a useful resource activity for a project to design a ski jacket, or an ice box. Since scientific concepts are best taught in a practical hands-on context, it is possible that the entire science curriculum could be covered by a series of design tasks, with key ideas highlighted as they emerge. The contextualisation of science in this way has support at primary level:

> "Science experiments can be meaningless to pupils unless they are placed in a practical context that they can identify with, and which gives their activities a sense of purpose." (Makiya and Rogers, 1992, p. 58)

There have even been suggestions, from research findings in psychology, that the 'situated cognition' (McCormick and Murphy 1994) of children unable to transfer their scientific knowledge to a design context, can actually work to their advantage in understanding abstract concepts from the other direction:

> "Skills that children seem not to possess in experimental laboratory tasks seem well developed when the same children meet similar (or even identical) problems in familiar, everyday contexts. Thus scientific thinking (logic, analysis, comprehension) seems intricately interwoven with the context of the problem to be solved." (Furnham, 1992, p.32)

At a secondary level, the rise in status of technology is also beginning to produce changes in this direction:

> "From a situation in which technology was a subordinate of science education, the reversal to science as service subject for technology education had occurred with remarkable speed." (Layton, 1993, p. 20)

Is this the future of science and technology education? Not if its critics are to be taken seriously.

Criticisms of the materialist view

Most criticisms of this view centre around the belief that it tips the balance too far in the direction of technology. Although valid to describe scientific dependence on technology for ideas up until the middle of the 19th Century, it is argued that this model does not adequately portray the highly scientific nature of much contemporary technological innovation:

> "Modern technology is deliberately scientific, in that there is continuous formal study and empirical investigation of aspects of technique, in addition to the mere accumulation of experience from successfully accomplished tasks." (Ziman 1968, p. 24)

From an educational standpoint, the subsuming of science learning within the practical context of technology risks putting an impossible load on the technology curriculum:

"...the teacher's emphasis on knowledge in a task may lead to a task structure that is dominated by the apparent conceptual demands, with the teacher paying insufficient attention to an analysis of the needs of the task or the demands of knowledge for action." (McCormick and Murphy, 1994, p.8)

Such an approach also calls for rather a hit-or-miss attitude to the science curriculum – that which will be taught is limited to what 'comes up' in the course of design and technology projects:

"This is a very attractive approach but is extremely difficult to bring off unless you are prepared to regard the whole of the science curriculum...as disposable." (Black, 1995, p.6)

Whilst there are clear educational benefits to be gained by framing the science curriculum in this way, perhaps an approach which can redress the balance between the two subjects will provide a more realistic solution.

5. Science and technology as interactive

Few would claim, in a nuclear age, that technology still owes little to science. Those adopting an *interactionist* perspective would point out that the roles of professionals in both fields are often intertwined, particularly in the area of research and development:

"Certainly at the level of individual scientists and technologists today, whether in industry or academia, their work may entail both scientific investigations and experimentation and the design and construction of new systems and instrumentalities of various kinds." (Layton 1993, p. 41)

What this view suggests is that science is not a uniform activity, actually comprising 'pure or fundamental', 'strategic' and 'applied' strands, each being distinguished by the degree of interaction with the world of technology. Science, Layton argues, makes vital contributions in a number of specific areas:

"The method of establishing facts by carefully controlled experiments is an important contribution of science to technology...A second way in which science serves technology is by contributing to the assurance and control of the quality of technological products and of the components and materials used in their production." (Layton, 1993, p. 44)

In some ways the interactive position is a 'fudge': a compromise between all the other views we have explored. But, its proponents might argue, the avoidance of extremes actually results in a view which mirrors most accurately the 'real' relationship between science and technology.

Implications for the curriculum of an interactive approach

The equal and complementary nature of science and technology is well established within educational rhetoric and official policy:

"(Science and Technology) should be seen as equal and interactive: technology makes creative use of science; science makes creative use of technology. Both involve evaluation in terms of their end outcomes, both have theories, processes, techniques and competencies which are all their own." (Bentley and Watts, 1994, p.5)

"The Association for Science Education believes that Science and Technology are inextricably interwoven. For this reason, it is important to develop the relationship between the two, but not to deny the distinctive features or the separate identity of either." (ASE 1991, policy statement)

"Clearly, there are important connections between science and design & technology: science draws on design & technology in developing its instrumentation and techniques of enquiry; significant discoveries have depended on the development of particular tools, materials or techniques." (NCC 1989, Science Non-Statutory guidance para. 5.2)

The problem is that representing the complex interactions between science and technology in the primary curriculum is very difficult. The cross curricular problem-solving approach could be adopted, but it would risk blurring the important distinctions between the two areas in the minds of teachers and children. One solution, proposed by Harrison and Black (1985) is 'Task-Action-Capablility', in which practical activities, conceived in terms of science investigations or design projects, would be supported by resource tasks which could be drawn from either area:

> "The model...expresses the conviction that Task and Resource interact in both directions. Tasks motivate and stimulate Resource studies as well as depending on and drawing on them. It follows that the curriculum must achieve a close dialogue, both in temporal sequence and in style, between Task activities and Resource activities." (Black and Harrison, 1985, p. 24)

Through this interaction of tasks and resources children would be developing holistic scientific capability and holistic technological capability, aware of the differences between them but also of how they draw upon one another. Such an approach has influenced the Nuffield Design and Technology Project (Barlex et al 1995), and there are clear possibilities for linking the primary version of this with Nuffield Primary Science (Wadsworth et al 1993). One advantage of such an approach is that it seeks to mirror the way scientists and technologists work together in society as part of the research and development (R&D) system. In this way it is possible that society as a whole will gain a clearer understanding of how R&D works, and hence a greater say in its output:

> "The R&D system is remarkably self contained and closed in on itself; what scientists and technologists believe about the dynamics of putting science to use is part of that dynamics; the educational system is one of the few input terminals to this peculiar black box." (Ziman 1980, p. 95)

In this way we as a society can more carefully monitor the ecological and social effects of what our scientists and technologists are doing.

Criticisms of an interactionist view

It is difficult to criticise a position which represents a compromise between other points of view, apart from pointing out that it is just that – a compromise. It perhaps paints an unrealistically rosy picture of the relationship between the scientific and technological communities. Theory and practice do not always sit happily together, and many scientists will claim a higher status for their lofty conceptual frameworks than the pragmatic engineer or designer, who may dismiss science as too abstract to be useful.

Educationally it can be argued that the high ideals expressed in policy statements rarely find their way into the classroom. Practically it is very difficult to teach science and technology interactively; teachers must simply deploy a range of approaches, hoping that children make links between the two areas. Clearly there is a long way to go in terms of curriculum development before school are able to take on the following challenge:

> "The educational interaction of science and design & technology is powerful and each school will need to organise its curriculum so that the way in which design & technology interacts with science... allows both to capitalise on the support each gives the other. Teachers will need to take account of the pupils' perspective on how coherent this area of the curriculum appears." (NCC 1989, para.. 5.3)

It takes little reading between the lines of this article to realise that it is the interactionist view with which the author has most sympathy (as indeed does Gardner, who proposed the model). It may be, however, that this is not the only way of representing the range of view on this subject.

Conclusion – towards a reformulation of Gardner's model

As I began to explore Gardner's (1994) categories and find support for each, I realised that they were not really mutually exclusive. The authors I read often straddled two or more positions, and could be brought in on either side of a particular argument. I began to move towards a representation of these views as lying along continuous axes, concerned with the degree of distinction drawn between science and technology, and the comparative status given to each, as in the figure below:

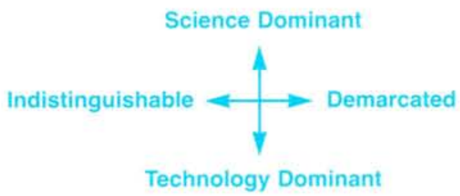

Figure 1

On this representation, the indistinguishable and demarcationist perspectives clearly lie at opposite ends of the horizontal axis, as do the TAS and materialist views on the vertical axis. The interactionist position is probably somewhere in the middle, and the views of an individual person could be represented as a scatter of points in one or more quadrant. This is the model I am beginning to use to explore the perceptions of primary teachers and student teachers, relating their espoused views to the ways in which they choose to teach science, design and technology in the classroom. It may not be important which view you take, or where you are on the axes, as long as you are aware that you are taking it, and that other views are also possible. The best position to see the others from may be the centre, but that remains for me to discover!

If you are interested in discussing this research or making a suggestion, please contact me on 0171 919 7320, or email d.davies@gold.ac.uk

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