VALUES AND BELIEFS IN SCIENCE AND TECHNOLOGY EDUCATION

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN THE DEPARTMENT OF EDUCATIONAL STUDIES UNIVERSITY OF SURREY 1994
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ABSTRACT

The motivation for this thesis arose from personal dissatisfaction with the way I was tutoring in-service courses on biotechnology for teachers. Biotechnology is an area of science and technology which raises many controversial issues and I felt unable to discuss in a meaningful way such issues. I therefore began to research into the inclusion of value issues in science and technology education.

The literature indicated that values are fundamental in decision-making and that values are a consequence of the beliefs, constructs or frameworks of meaning people hold. A study of the literature about the nature of technology and science was followed by a brief review of the inclusion of values in education. The area for the research was identified as educators' beliefs and perceptions about science and technology and the influence of these on the inclusion of awareness of values in teaching.

Adopting an interpretive methodology, in-depth interviews were the main research technique but the interview questions were derived from the quantitative analysis of a questionnaire.

The main research findings indicate that educators believe that science is socially constructed knowledge and that all aspects of technology are value-laden, yet the same educators present a positivistic, impersonal view of science and the only values addressed in technology are related to economics and marketability. It is postulated that an impersonal, deterministic image of science and technology is not conducive to the inclusion of a wide range of values. In the concluding chapters the need for educators to reflect on their beliefs is emphasised and possible ways to do this explored.
ACKNOWLEDGEMENTS

I would like to thank my supervisor Bob Brownhill and many colleagues at the University of Surrey namely: Pam Denicolo, Jacky Tivers, Joan Parnell and John Hobrough. I owe a great debt to Annette Stannett for her encouragement, guidance and direction and for proof reading the final version of the thesis. My special thanks are due also to Josie Gregory for her encouragement particularly during the last stages. I also wish to acknowledge Josie and Anne Lee for their friendship, encouragement and support at our PhD meetings and lunches. Thanks are also due to fellow students Michele Linehan, Arnaldo Vaz and Steve Alsop for their time, ideas and comments.

There are many friends and relatives who have supported me, cared for me and believed in me, too many to mention by name. However I must mention Ruth Conway, who has been a constant inspiration, support and friend and Jean Dawson for her patience and help with word processing when I had to change systems. My special thanks and love go to my sister Sue and my children Sue and Paul who have always been there encouraging, believing in me and loving me. Without all these special, generous people this thesis would not have been written.
INTRODUCTION

For two years from 1987-1989 I provided in-service training (INSET) for school teachers. All the courses I provided were concerned with biotechnology for I was sponsored by a government agency to encourage the introduction of biotechnology into the school curriculum. During this time I became increasingly concerned about the picture of biotechnology I was presenting to the teachers.

When I first started providing INSET, my courses included only ‘factual’ knowledge of biotechnological developments yet I knew that much of the material I was presenting was controversial - such as, for example, genetic manipulation techniques which raise considerable ethical and moral issues.

Biotechnology is about engineering change in biological systems to enable such systems to be used by humankind. The ability to alter the structure of genes provides many opportunities for benefiting humans; it may however present great hazards:

The genetic engineer claims to be providing society with a vast range of innovations, such as more effective and cheaper pharmaceutical products, more abundant food crops, new approaches to the generation of energy, the recovery of resources and pollution control, and the diagnosis and correction of genetic disorders. On the other hand, as a result of the application of genetic engineering, worldwide pandemic caused by newly created pathogens, the triggering of catastrophic ecological imbalances by the release of novel organisms into the environment, the creation of new agents of biological warfare and the increased power to manipulate and control people, may each become realities in the near future. (Wheale and McNally, 1988:xv)

Biotechnology occupies an interesting place in any discussion of modern science and technology. Within a relatively short time, about forty years, we have seen the development of new theories, new techniques arising from the theories, and new opportunities to exploit the techniques. These opportunities challenge us to consider
the role and responsibility of science as never before. Biotechnology also provides extensive examples for discussing the nature of science and technology, the purposes of these and the values involved when making decisions. For example the mapping of the human genome is stimulating discussion and concern about a new eugenics movement (Wheale and McNally, 1988).

As an INSET tutor I did not initially consider the value-laden nature of the knowledge I was transmitting. Perhaps I was suppressing, or at least not acknowledging to myself, that it was value-laden; maybe I did not see raising awareness of value issues to be part of my role. Looking back I see that the discomfort and dis-ease with my teaching was increased by discussions with participant teachers, by reading articles and books and by listening to the radio and television. A further stimulus was the publication of the National Curriculum Science and Technology Orders in 1989 and 1990 respectively.

Both the science and technology documents, issued in 1989 and 1990 respectively, required pupils to be aware of 'values' issues. For example in the original Science Statutory Order are the statements that pupils should:

* be able to make informed judgements about the economic, social and ethical issues concerning the recent developments in genetic engineering;
* be able to select and weigh evidence to form reasoned judgements about some of the major ecological issues facing society;
* understand and be able to discuss the implications of information and control technology for everyday life;
* develop their understanding of the ways in which scientific ideas change through time and how the nature of these ideas and the uses to which they are put are affected by the social, moral, spiritual and cultural contexts in which they are developed; in doing so, they should begin to recognise that while science is an important way of thinking about experience, it is not the only way.

(National Curriculum Science, 1989: 11, 13, 27, 36)
And in the Technology Order:

* IDENTIFYING NEEDS AND OPPORTUNITIES - Pupils should be able to state clearly needs and opportunities for design and technological activities through investigation of the contexts of home, school, recreation, community, business and industry.

* EVALUATING - Pupils should be able to develop, communicate and act upon an evaluation of the processes, products and effects of their design and technological activities and of those of others, including those from other times and cultures. (National Curriculum Technology, 1990:3,15)

One statement in particular made a considerable impression on me "...while science is an important way of thinking about experience, it is not the only way"(National Curriculum Science, 1989:36).

These statements challenged me to reflect and question my role as a teacher and they also introduced new dimensions into my thinking about science and technology. I realised that I had never questioned my understanding and beliefs about the nature of science and technology. I felt challenged to examine my intuitive theories of science and technology and consider and evaluate other ways of explaining human experience.

At the same time that this unease was growing, I was gaining confidence as a tutor and I gradually began to introduce awareness of the possible impact of biotechnological developments on individuals and societies. I was careful to include possible benefits as well as potential hazards; I tried to present an unbiased view and yet I became increasingly aware of my lack of skill and expertise to do this.

By reflecting on my feelings, my knowledge and my experience, I tried to conceptualise and analyse my concerns. These seem to be centred around the perceptions I had of the nature of science and technology and a lack of understanding about how decisions about scientific and technological developments are made. I knew I had to start by questioning my understanding; only when I had attempted this could I investigate and
question the understanding of others in these matters and consequently engage in a process of education with them. The more I read, thought and discussed how decisions are made in technology, the more I realised that elemental in this are the values people hold.

I joined the steering groups of two national bodies, NAVET (National Association of Values in Education and Training) and the Network of Beliefs and Values in Technology Education. This increased the opportunities for wider reading and discussion and also meant I felt pressure to write.

My literature search included material on the nature of technology and of science, and explanations of values and beliefs. This reading coupled with more or less continual writing, enabled me to clarify my understanding of the areas to be studied and I began to see possible research questions. The format of this thesis reflects the stages of the research from the initial reading to the findings from the research.
CHAPTER I VALUES AND BELIEFS

If one believes in nothing, if nothing makes sense, if we can assert no value whatever, everything is permissible and nothing important. There is no pro or con; the murderer is neither right or wrong. One is free to stoke the crematory fires, or to give one's life to the care of lepers. Wickedness and virtue are just accident or whim. (Albert Camus, *The Rebel*, 1951)

1.0 Definitions

The meanings of a number of words used in the thesis need to be clarified; words such as assumptions, attitudes, values, beliefs, constructs and morals. Defining the terms is an epistemological matter. A multi-disciplinary approach to the issue brings confusion yet also enhances analysis and comprehension. Meanings for the terms differ according to the context in which they are used so no definitive understanding can be given. Yet all these words are used frequently in common parlance so some agreed meaning has to be presented.

1.1 Assumptions

Assumptions are connected with beliefs, they are 'things' which are taken to be true. The implication is that they have not been rationalised or tested. Assumptions are not substantiated and may be based on ignorance or arrogance, they may also be assumptions which can be said to be reasonable in that they can be explained or rationalised. In the context of this thesis assumptions are propositions which have not been tested but which can be justified in some way.

1.2 Attitudes

An attitude is a mental construct which attempts to make sense of a person's behaviour past or present towards some person or object. Attitudes are also used to predict future behaviour. Allport defines an attitude as:

a mental and neural state of readiness, organized through experience, exerting a directive and dynamic influence upon the individual's response to all objects and situations to which it is related. A learned predisposition to act in a consistently favourable or unfavourable manner or in a neutral manner, (e.g. as
a judge or academic should be neutral) with respect to a given object (cited in Radford and Govier, 1980:643-644).

Other psychologists question the internal reality of attitudes and argue that as we know them, attitudes consist solely of the external constructs which we develop on the basis of our observations of consistencies among an individual's behaviour. (Radford and Govier, 1980:644)

Attitudes are linked with behaviour but a direct link between attitude and behaviour cannot be assumed. Attitudes predisposing towards a particular action or behaviour are only one aspect influencing the realisation of that behaviour. Intention to act is related to a person's attitude, and is influenced by normative beliefs about the act and motivation to comply with those norms. Motivation to comply is likely to vary according to the situation, particularly whether the person is in a private or public situation. People may also behave in a way which is at odds with their attitudes due to lack of knowledge. For example someone might have a positive attitude to some action but be unable to actually carry out the action because they lack knowledge or information. Awareness of the ways in which the attitude can be 'realised' may limit behaviour. For a number of reasons individuals may behave in ways which are incompatible with their values and ideals.

Attitude surveys are popular ways of gauging respondents' opinions. Sometimes an attitude survey actually asks about knowledge of a specific area which seems a misuse of the term. Attitude surveys often use Likert response scales with responses such as "Comfortable, Neutral, Uncomfortable" as in a survey about attitude to applications of genetic manipulation (Martin and Tait in Durant, 1992). It would be possible to add the word "feel" before each response e.g. I feel comfortable about. While it is impossible to separate knowledge and feelings, attitude surveys may be more accurately described as questions about feelings regarding certain situations or issues. To understand why a person holds an opinion or attitude it is necessary to investigate the beliefs he or she holds.
1.3 Values

A value is something held to be of relative worth by an individual and to which that individual has a pro-attitude. It is something esteemed for its worth, merit or importance by the individual. The European Values Survey defined values thus:

Values are deeply rooted dispositions, orientations or motives guiding people to act or behave in a certain way. Values and beliefs are thus more complex, more basic and more enduring than attitudes, opinions and preferences... A single underlying value may be indicated by a range of expressed opinions or behavioural indicators. (Barker et al, 1993:4)

Values are all pervasive for they are one’s judgement of what is important and of worth in life. Values personal or communal, are chosen, adapted and altered by individuals as a consequence of experience. Inevitably perhaps, the term is used ‘loosely’ as is indicated by the fact that it is defined differently within each of the social sciences. (Kilmann, 1981). In sociological terms, values are ideals (such as justice, peace, integrity), customs or institutions for which people of the group have an affective regard. For example a person might think that all people should be treated in an egalitarian way when equality is the value. It should be noted that people can apparently hold the same value but give it a different meaning, for example the value justice. One person may think it just to reward people according to the amount of work they have done, while another person may wish to reward people on the basis of need.

Groups usually hold the same or similar values but it cannot be assumed that because an individual belongs to a group or institution, he or she upholds the values of the institution or group. This indicates a psychological picture of values, namely that they are factors prized by, or necessary for the individual and are manifested as the individual’s attitudes and norms.

Horley (1991) notes that a common understanding of values emerges from a variety of disciplines.

To talk of an individual’s values is to refer to a system of learned beliefs concerning preferential objects, modes of conduct, and/or existential end states.
Values include "what is wanted, what is best, what is desirable or preferable, what ought to be done". (Schiebe, 1970: 42)

In other words, values provide standards against which to evaluate things, people, and ideas. Another generally accepted aspect of values is that they represent the essence or basic identity of an individual.

People come to see themselves, and others come to see them, by the standards that seem to guide their affairs. (Horley, 1991: 4)

1.4 Values and human need

Values as the 'essence' of the human condition, links with an existentialist view, that awareness of what it means to be human is the basis of universal values. According to the existentialist point of view, human life generates values and these values are the only ones actually realisable and genuinely worthy of pursuit. If the human condition is fundamentally the same for all individuals, then there are certain universal features of human life. Maslow's hierarchy of basic human needs may be a starting point for identifying values which might be termed 'universal values'.

![Figure 1.1. A hierarchy of needs. (Child, 1973: 36)
Such needs might at least provide contexts in which values have meaning. If there is a set of universal values such a set will presumably be concerned with enabling humans to attain these needs. Maslow recognised however, that there were incidences which did not conform to the hierarchical picture of need fulfilment, for example people who engage in great personal sacrifice to help others or who demonstrate clear heroism. At the very time Maslow was developing his theory in New York, there were those dying of disease and starvation in German concentration camps who were selflessly sharing their last crumbs with fellow inmates. He thought such conduct could be explained thus:

These people may be understood, at least in part [as having been] satisfied in their basic needs throughout their lives, particularly in their early years. [They] seem to develop exceptional power to withstand present or future thwarting of these needs simply because they have a strong, healthy character structure...It is just the ones who have loved and been well loved, who can hold out against hatred, rejection, or persecution. (in Hoffman, 1989:154)

There are other explanations. One might suggest that a person who has suffered great loss, all of his/her family and friends, for example, has nothing to live for. One might also see the act as altruism arising from a belief system or faith. ("Greater love has no-one than this, that he lay down his life for his friends". John: 15:13)

Research into moral development by Kohlberg (1984) identified six stages, or ways of thinking. At the sixth stage, the principled stage, appeal is made to universal principles of justice, reciprocity and equality of human rights and to the dignity of humans as individuals. A person at this stage wants to be respected not because she has obeyed the laws of society but rather because she has followed the inner dictates of her sense of what is right. This may be compared with the 'altruism' noted by Maslow. It is interesting to note that Kohlberg says 66% of Americans never go beyond stage four, the stage of fixed rules concerned with maintenance of order in society. He also notes that the stages are not dependent on religion although religion is an important factor in the elaboration of moral themes in different cultures.
1.5 In a different voice

Until the research carried out by Gilligan, the picture of moral development was considered to apply equally well to women as to men. All research to 1982 was carried out on males. Gilligan is critical of Kohlberg’s, Freud’s and Piaget’s explanations of women’s sense of justice. Lever (1976), observing play, extended and reinforced the work of Piaget, noting that boys follow rules whereas girls have a more pragmatic attitude towards rules "regarding a rule as good so long as the game repaid it" (Gilligan, 1982:10).

Gilligan suggests that women construct moral problems in a different way from men and that the difference arises from the traditional traits which define the female role - care and sensitivity to the needs of others. For women:

... the moral problem arises from conflicting responsibilities rather than from competing rights and requires for its resolution a mode of thinking that is contextual and narrative rather than formal and abstract. This conception of morality as concerned with the activity of care centers moral development around the understanding of responsibility and relationships, just as the conception of morality as fairness ties moral development to the understanding of rights and rules. (Gilligan, 1982:19)

Women’s emphasis on responsibility and relationships means that women are context bound and that they come to question the normality of their feelings and to alter their judgements in deference to others. Women are anxious about competitive achievement and whereas men are motivated to achieve success, women are motivated to avoid failure (Horner, 1972; McClelland, 1975). Accepting that these are generalisations, if the differences in moral decision making between the sexes are acknowledged, it is appropriate to say also that the values of women differ often from the values which have been made by the other sex (Woolf, 1929:76).

1.6 Universal values?

The above discussion indicates the need to look at the relationship between individual and shared values and to ask whether there can be universal values. If there are
universal values, these presumably will be concerned with human experience, perhaps with enabling all humans to attain the basic needs for survival and well being. It may appear that individuals and groups display attitudes and act in ways which are contrary to this. There often appears to be a mismatch between commonly held/universal values and personal values or at least expression of the values; a difference between what is and what ought to be. Put another way, can human experience be used as the basis of a value system and, if it can, how may individuality and uniqueness be acknowledged?

Kurti believes this is possible; it is a question of degree. Each person must realise their own values and desires while assuming the responsibility within the parameters of human existence which embrace certain human (and thereby universal) features. These features do not change. Each ... brings to bear upon the task certain social customs, environmental conditions and individual preferences, all of which are constantly changing and evolving. All these factors operate within the universal arena and thereby influence the manner in which we execute our basic desires. There is a certain primacy enjoyed by the basic value judgements which are rooted in the universal features of the human condition. Preferences such as those determined by social customs are always secondary. If we accept a fundamental similarity between the hopes of individuals together with a similarity between the means whereby these hopes may be realized, the existentialist claim to a norm in the form of universal validity for its own value orientation is much stronger. (Kurti, 1990:2)

It could be assumed that the expression of values, i.e. in behaviour, is concerned only with the human condition. This is not so, for value issues also relate to animal welfare and the environment. These are complex issues. There is no way of knowing whether people hold values concerned with the preservation of animals or the environment, completely separate from human welfare and survival. This is illustrated by Lovelock’s Gaia hypothesis (1979). Human beings do not need to be concerned about the planet itself, by synergetic reactions balance will be restored; the effect of human pollution will be temporary. What will not be ensured by the same natural processes
is the survival of the human race. In a similar way values related to animal welfare may arise from concern about human distress related to empathic anthropomorphism, or they may arise from concern about the sanctity of all life (it is probable that they arise from both).

In talking of the sanctity of life or the survival of the human race one is talking of beliefs held by individuals and by groups. The relationship between values and beliefs is discussed later but first, in order to focus the ensuing discussion, the process or activity of using values i.e. valuing is discussed.

1.7 Valuing
In a speech at the Malvern Conference the Archbishop of Canterbury said "Europe needs a body of common values" (Carey, 1991). A statement such as this lacks clarity and seems to assume a certain understanding. It says nothing about the context and criteria of relevance. Nor does it say anything about the values which are to be held. Does the Archbishop mean values such as avarice or justice, indifference or compassion? Would it be clearer if he referred to a body of common principles? It would seem that he is suggesting we would feel more secure if there were a common value system with a common language. Yet:

A theory of value is a theory about what things in the world are good, desirable, and important. Such theories aim at answering a practical rather than a purely theoretical question since to conclude that a state of affairs is good is to have a reason for acting so as to bring it about or, if it exists already, to maintain it. (Flew, 1983:365)

This is illustrated by the following discussion of a practical seminar which involved valuing:

During discussion on the situations, emphasis was put on the necessity to justify proposed courses of action by reference to principles and values and that these principles and values had themselves to be justified in accordance with the hierarchy of preferences in the structure of our values systems. (Brownhill, 1971:298)
Values are also said to be one’s principles or standards but there is a problem here. “Principles are standards which one is taught or on which one decides for oneself, and which are used to judge the merits of objects of a certain class, they are involved in choosing between objects within the class” (Hare, 1986:134).

Defining principles like this, they are seen to be close to value-judgements but as Hare implies, principles can be stated, they are rules for action and are explicit whereas values are often non-coherent, implicit, inconsistent. In law, for example, although principles are invoked, juries and judges listen to both sides of the case and justify their decisions with reference to values of justice, equality and democracy and these same principles have been formulated with reference to the law makers’ values. Principles may however be justified because certain values are exhibited although the values are not acknowledged, for "People are so used to their values that they just accept them without questioning" (Watson, 1990).

Values are often unarticulated and unidentified. It may therefore be better to talk of valuing, where the implication is that the individual holds something to be of worth or value within a particular context and that within that context value judgements can be made explicit and justified.

1.8 Values and Facts
Sometimes ‘facts’ are contrasted with ‘values’ (Midgley, 1992; Brew, 1991). This is possible if facts are seen as objective knowledge while values are seen as non-coherent, implicit and inconsistent and that in saying ‘objective’ the implication is that facts can be supported and justified i.e. are explicit. However this is not necessarily the case. McPherson comments:

In some contexts, the facts are what we agree to accept as reliable and right, so that we can concentrate on arguing about what else we should believe to be the case, or to be worth doing or desiring. In other contexts, facts are valuable as actual or potential objects of attention, interest or effort. The ways in which facts enter into our attention and language are shaped by our selectiveness and so by our valuing, as we go for whatever seems more relevant to our valued
goals, whether these relate to understanding, behaviour or appreciation. Accounts of 'facts', as if existing in some untouched purity beyond all such interactive values, are closer to fairy tales than to science... the contrast of values with counter-values or disvalues is more significant than the manner of speaking which contrasts 'values' with 'facts'. (McPherson, 1990:6-7)

Values influence decisions made by individuals and groups, yet in making choices, values are often overlooked and their influence is not realised. While acknowledging the tacit and value dimensions in defining facts, if facts are mental concepts or models which are accepted and agreed, the implication is that they have to be supported by reason or evidence. Facts are things we believe exist and can at least, in theory, produce empirical evidence for. In a similar way values need to be justified. Values are attitudes, i.e. feelings about tendencies to act which we hold and may be able to justify. If there is no reasoning or justification, it is impossible to distinguish facts or values from assumptions or prejudices.

1.9 Beliefs
Valuing involves evaluating and decision-making. It is a process carried out both by individuals, and by groups. In either case the values which influence the evaluation or the decision making are likely to be a mixture of personal, individual values and values held by a group or groups. An unavoidable factor in the analysis of valuing and the justification of values brought to bear is an understanding of the beliefs which are held by individuals or groups:

Beliefs are underlying convictions which determine what is valued, about the nature of existence, reality, other human beings and the world. Beliefs are expressed in most religious traditions and identified ideologies but they tend to be the hidden assumptions behind values statements which are not openly expressed. Belief is not purely rational or it would not be belief, but neither is it irrational to the point of denying human reason. Beliefs can be understood by reason but extend beyond the boundaries of human rationality. (Williams, 1990b:2)
It should not be assumed that all human behaviour is directed by values. Much daily, routine behaviour which appears to have little significance is a consequence of habit. In trying to understand the process of valuing, the researcher has to be aware of the possible existence of habitual behaviour and may have to be prepared to challenge such behaviour. He or she must also be aware of the social influences on individuals. People have affiliation to groups which share their beliefs and which understand their particular framework of meaning.

People are guided and behave according to their beliefs or frameworks of meaning. Beliefs are ways of interpreting and explaining the world. A philosophical explanation states that a believing person holds a proposition to be true where there is some degree of evidence, though not conclusive evidence, for the truth of the proposition. Values are closely associated with what people believe and how they see the world.

Values are grounded, even though at a completely unconscious level, to beliefs widely held in a community...Beliefs are seen as creeds/ideologies but they are really underlying assumptions by which people live. Beliefs are 'conditioned' into people. Most of us are in orbit around assumptions and beliefs. People need to be educated re assumptions and attitudes, just stating them is not enough. (Watson: 1990)

Watson implies that within the process of valuing, the aim should be to challenge assumptions and be explicit about beliefs.

Beliefs may be personal, communal or both. A communal belief system has:

- a set of linked ideas which are learned and shared and which have some permanence. Individuals and groups exhibit some commitment to these ideas. In order for the commitment to persist the ideas must be validated i.e. demonstrated to have value;
- some degree of social organisation;
- utility in group adaptation to strain or disorder;
- non-social aspects such as internal logic, that drive them in given directions regardless of the wishes of the believers.
One of the key elements of a belief system is the identification of values. A group will see itself setting out to do various things to implement these values or goals. But this needs to be approached with caution. Values are often perceived as 'a priori' when in fact they are 'a posteriori' to action. A course of action may be declared socially legitimate if it can be shown to derive from collective values (Borhek, 1975) but this can not be assumed: for example neo-nazi groups share values which are not legitimate for the majority of people.

A religious belief is probably the prime example of a communal belief system. People who believe in a supernatural deity see themselves living within a set structure of a pre-existing value system. This may be so, but individuals still hold a responsibility for the ordering of values, and for actions which are influenced by these values. Humanism is a faith or belief system which is not a theistic one. It is a belief system that is not absolute or dogmatic but is deeply involved with values.

It is statements about values and about the ideas and ideals we feel have worth that are at the root of Humanism. As human beings we have to rely on human resources and to co-operate and work with other human beings. We are responsible for our own actions and our belief is that we have a duty to be responsible towards other people. (Bondi, 1990:2)

Existentialists and humanists stress the significance of individual challenges and choices. It is claimed that the extent to which humans are able to exert free will varies. Different religions have varying concepts about the extent of human free will.

1.10 Faith
Belief and faith are closely linked. Beliefs need to be understood by reason but they are not the conclusions of rational thinking, neither is faith. Within the context of this discussion it is necessary to differentiate between the two terms.

Faith involves intuitive knowledge or experience. Intuition means knowing without being able to say how one comes to know; it is akin to having a hunch, to jumping at a solution to a problem without consciously having worked out the solution. One may
have a intuitive thought but never act on it. Faith involves venture; it involves acting on intuition or experience. Faith is giving absolute value to someone, something or an idea. For example a person may give absolute value to the possession of money. Such a person regards money as his or her principal weapon against everything that threatens them as a person. Money may be an ‘idol’ in which trust is placed and on which he or she relies in order to feel secure. Theistic religious teaching urges trust in a God or Gods on whom the individual can rely (Bryant, 1987).

It may be useful to think of ways of explaining and giving meaning to experience as a continuum:

Ungrounded opinion..Assumptions..Faith..Belief..Knowledge

The point at which and the extent to which an individual puts his or her trust may distinguish the stages of the continuum. Thus little trust may be placed in ungrounded opinions whereas considerable trust is placed in full knowledge.

1.11 Values and Beliefs as Constructs

Personal construct psychology sees the individual developing personal constructs which enable him or her to interact with the world (Radford and Govier, 1980). G.Kelly’s (1955) view of the individual as scientist implies that everyone uses their personal constructs to make predictions and decisions. Constructs are a means of discriminating between elements i.e. between observed items. An individual looks to see what aspects of a series of elements are similar to another and which are dissimilar.

Each construct is bipolar - that is to say it has what is known as an ‘emergent pole’ and a ‘contrast pole’. Both emergent and contrast poles together form the construct on the principle that one cannot tell that what one observes is anything specific without having something to contrast that with. (Dalton & Dunnett, 1990:7)

Fishbein and Ajzen (1975) described a value as a bi-polar evaluation. But values are not necessarily bi-polar concepts. Sweet and sour are bi-polar concepts yet something
thought to be sweet by one person may be considered sour by another. Similarly freedom and determinism may be seen as opposites yet there is freedom within the constraints of determinism. Thus an object is free to drop or be dropped within the constraints of gravity.

A link between constructs and values is often made thus it is necessary to examine an individual’s personal construct system in order to understand the individual’s attitudes and underlying values. (Zanna and Krisfiansen, 1986)

In Personal Construct Psychology (PCP), a core construct is a construct that governs a person’s maintenance processes (Kelly, G., 1955). Core constructs are the means of self-identity. They are "tied to a set of roles and relationships within a given social order, and allow an individual to function socially and thus secure continued existence" (Horley, 1991:5).

Horley thinks that the terms values and core constructs can be used interchangeably. He justifies this by stating that as core constructs are related to social interaction and values are described in terms of evaluation of modes of human conduct, there is a similarity. He qualifies this statement when he then goes on to say that interpersonal values and moral/ethical values are interchangeable terms. As evidence for this he quotes Rokeach:

Moral values refers to those [values] that have an interpersonal focus which, when violated, arouse pangs of conscience and feelings of guilt for wrongdoing. (Rokeach, 1973:502)

and relates this to Kelly’s statement that:

perceptions of one’s apparent dislodgment from his core role structure constitutes the experience of guilt. (Kelly, G., 1955:502)

However as Horley notes "core role constructs do not exhaust the fund of core constructs, just as moral, ethical, and interpersonal values do not exhaust all values" (1991:6).
He concludes that core role construction in PCP corresponds to an important subset of values (i.e. moral values) and not to values in general.

In that personal constructs are used to interpret and explain the world, they are often called beliefs (Dicker, 1984). Schiebe (1970) describes them as akin to beliefs. Horley states that values are a special type of belief and that there are nonvalue beliefs which he calls ordinary beliefs. These ordinary beliefs are propositions about the nature of the world (past, present and future). This is in line with the view that beliefs are the basic building blocks of knowledge systems (Egan, 1986). If one knows something one presumably also believes it; knowledge is just beliefs. These ‘ordinary beliefs’ could presumably be described as facts; thus Horley seems to be acknowledging a distinction between facts and values which begs the question: what are facts?

Some psychologists see belief as an outdated term from folk culture (Stich, 1983) but it can be argued that this cannot be so for the term is still widely used in society. Ordinary beliefs appear to function as peripheral constructs ie non-core constructs which do not play a role in self-identity. This may be true but there are other considerations such as environmental factors which are involved in self-identity. Becoming the person one wishes to become depends on the tolerance of the society to which one belongs and the interaction of the individual with others (Rogers, 1982). Physical factors and environmental factors also have influence.

Many peripheral constructs are a result of formal education and can be altered or easily replaced. This is the case in psychotherapy. Peripheral constructs and beliefs can be equated in the way they are expressed, for example both may be propositional. Constructs are linked with a set of elements (e.g. foods) and construct pairs, e.g. sweet and sour. Values are often seen as elementless, for example values such as justice, peace, happiness. How can such values be related to constructs linked with elements and bipolarity (assuming that bi-polarity is an acceptable way of defining values)? Is this just a matter of form, of linguistic tradition as Horley suggests?

It is an easy matter to express a typical value using a belief format (e.g. "I believe that John is happy"). It is no easy matter, however to determine
precisely what is a value and what is an ordinary belief or, to use the terminology suggested herein, what is a core construct and what is a peripheral construct. Probes of individual respondents are demanded unless, like most of the work done to date, one wants to make assumptions about the use of particular values and ordinary beliefs held by members of given cultures. (Horley, 1991:9)

The PCP approach to values and beliefs indicates that values are not static; they may or may not be stable. While acknowledging that individuals may possess only a few core constructs / core values, it should not be assumed that members of the same group or culture possess the same constructs or that these can easily be accessed.

PCP uses various techniques to access values and ordinary beliefs such as Rank-ordering, Attitude scaling and Repertory Grids. A value-free assessment technique is however, impossible, for all are concerned with the individual's meaning and use of a particular value term and how it is related to other values in his or her value system... At issue is the individual's highly complex value system and equally complex and interconnected system of ordinary beliefs. (Horley, 1991:11)

It is likely that any one technique will be inadequate and a variety of approaches are needed.

Finally a further indication of the difficulties inherent in investigating beliefs and values:

If the popularity in psychology of values and belief is due to lack of connection with a specific theory, acceptance of the foregoing perspective might limit the use of value and belief. No longer could they be all things to all people. Those who would use the terms, however, would have a better understanding of the constructs. (Horley, 1991:12)
1.12 Morals

Trying to distinguish between values, ethics and morals is very difficult and confusing. The terms are clearly connected. Horley suggests a useful way of interpreting the connection:

Morals can be seen as a subset of the major set which is the set of values - another subset would be ethical values. Moral values are used to evaluate human behaviour, either one's own (planned or enacted) or others' behaviour. (1991:5)

When faced with a number of alternative options, an individual has to choose a course of action, to decide how to behave; the person's conduct can reveal the moral principles s/he holds although it is impossible to judge whether a person is acting morally from their action.

To become morally adult is...to learn to use "ought" sentences in the realisation that they can only be verified by reference to a standard or set of principles which we have made by our own decision accepted and made our own. (Hare, 1986:196)

In making the standards or principles our own we may be making subjective judgements but the set of standards or principles have public expediency. Morality is a public as well as a private activity. The sources of authority for moral beliefs come from one or a combination of custom, religion/ideology, and secular rationality. Indeed the word moral comes from the latin 'moralis' meaning customs or manners.

Secular rationality appeals to those who seek to identify moral principles that can be universalized to all mankind, regardless of nationality and religious preference. ...To search for a rational basis for moral authority has the same anti-authoritarian characteristics as science. Just as science does not respect authority but commands evidence, so rational morality suspects authoritative views - whether from parents, tribal chiefs, priests, or party leaders - and demands reasons. However, science and secular rationality are not the same. Science can help us determine the facts and tell us what caused events to occur, but it cannot tell us what to do about them. (Mehlinger in Frazer and Kornhauser, 1986:24)
To act morally the person must be aware of the moral belief; he or she must have the skills and knowledge to practise the belief, and must have the commitment to act on the belief, even in the face of adversity. But reasonable people often differ about what is the right thing to do.

Morality based on rationality will not provide a set of boxed rules that can be applied unequivocally in all circumstances. Acting rationally in matters of morality requires people to reason through alternative actions in an effort to find the best solution given the particular circumstances that seem most likely to be justified in accord with fundamental moral principles. Morality based on rationality provides a middle ground between the two poles of dogmatism and ethical relativism. The moral rationalists reject the idea that there are no universal moral principles, thereby freeing people to do whatever they like; they also resist the demand that they conform to a code of conduct stipulated by an external authority, whether the authority is a church, a government, or tradition. (Mehlinger in Frazer and Kornhauser, 1986:25)

A morally educated person is someone who thinks and acts morally. To function effectively the morally educated person requires considerable 'factual' knowledge such as the knowledge of likely consequences to be able to judge the likely consequences. He or she must be able to relate to people, be able to communicate ideas, be able to empathise with others, to understand their feelings and their perspectives on a situation to respect and see as important such feelings and perspectives. In addition they must be able to understand a situation apart from their own emotional interest in the outcome and they must be committed to act morally and be prepared to accept the adversity that frequently accompanies acting in a moral way.

1.13 Ethics
Ethics include standards, principles and concepts which regulate behaviour in a given field of human thought or activity. They are formal theoretical statements which intellectualise morals and involve professional values such as those seen on professional codes or statements about research enquiries. Morals refer to values or principles which
are less formal, more personal and subjective and to which the person is committed. Ethics and morals are concerned with what ought to be done.

Ethical knowledge will not provide answers to moral questions, nor will it avoid having to make ethical choices, but it will at least provide the basis for making decisions about ethical problems and engender the individual's interest in the process of justifying ethical actions. (Rodmell, 1988:42)

Faced with an ethical problem one can ask:

Is it governed by an accepted ethical standard? Acceptance and application of such standards implies universality, i.e. an individual 'always should choose to act as all human beings should choose to act in a similar situation.' (Curtin and Flaherty, 1982:49)

An ethical standard in medicine such as - 'killing humans is wrong', seems to lay down clear guidelines for doctors and nurses, but does it? Taken literally, euthanasia and abortion* are forbidden, yet these are areas of continuing discussion and controversy. The existence of such a standard has led to considerable heartsearching by doctors and nurses, heartsearching which is different from that of the politician, theologian or voter. Acceptance or rejection of the standard influences the actions of the individual in different ways in different contexts. For doctors and nurses working under a code of medical ethics, there are expectations and imposition of sanctions which determine decision making and behaviour. As ordinary members of society, doctors, nurses, politicians may decide to kill or not to kill another human. In making this decision a different code of ethics may be involved, eg. religious ethics or it may be knowledge of the secular law and fear of sanctions. A politician is in a different position for s/he is asked to define and determine the law, and this is closely related to defining a code of ethics. In order to do this the politician will hopefully, consult and collect information on personal and societal experience; but somewhere in the process personal values or morals will be brought to bear (it is acknowledged that politicians sometimes vote according to their conscience rather than on party lines). Values and morals impinge on decision making by everyone. The degree or influence may vary however, and the influence may be overt or covert.
Some writers argue that euthanasia and abortion debates indicate a plurality of values where there are no common values. Maclntyre (1981) suggests however that there has to be a background of general agreement against which disputes arise.

1.14 Frameworks of meaning

Moral action is acting according to a set of principles accepted by oneself, or according to a liberal or neo-Kantian view, principles which one has freely chosen and not just accepted. Prerequisite to becoming a rational person is the process of experiential learning that is reflecting on experience and evaluating that experience. This experience will necessarily include customs, mores, norms and traditional beliefs. As a consequence of learning, a set of principles are acquired. The set of principles may not be unique to the 'moral learner'. Indeed the 'learner' is likely to affirm a set of principles which overlap, to a greater or lesser extent, with a group, body or society to which the learner belongs. Acting in accordance with a set of principles which have been formulated by external bodies without 'owning' the principles is not truly moral action. This does not however exclude the possibility of an individual acting autonomously and the action agreeing with an external code of behaviour. Principles, ethical stances, moral positions are elements within a framework of meaning or interpretation.

1.15 Summary

This thesis is concerned with decision-making in science and technology, a process which involves value-judgements and hence values. I might have chosen to explore attitudes rather than values. My reading of psychological texts suggests that attitudes are akin to opinions or feelings and are a consequence of the values and beliefs people hold. Saying that attitudes explain and predict behaviour suggests a process which is external to the individual or group doing the decision-making. I have chosen to investigate values rather than attitudes, for the aim is to make explicit the values which people are bringing to their decision-making. If I had explored attitudes, then making the values explicit would be more difficult and the justification for how decisions are made might remain at the level of opinion, assumption or prejudice. Attitudes are too shallow and too superficial.
A major, personal discovery from reading the literature has been the realisation that I need to investigate the basis from which values arise. This basis may be described as belief, constructs, frameworks of meaning or ways of perceiving or interpreting. I anticipate that looking at values rather than attitudes will enable me to probe deeper into the beliefs and frameworks of meaning. It will also help those involved in decision-making to explicate elements of this process which they carry out. Turner and Wynne (1992) provide a useful way forward for doing this with regard to decision-making about nuclear energy:

...someone may believe nuclear energy is cheap and abundant, and also a threat to decentralised forms of society. If they regard energy use as extravagant and the cost unimportant, but are strongly concerned about civil liberties, then nuclear energy will be judged unacceptable. Thus there are three steps:

1. What clusters of beliefs do people hold about a technology?
2. What are the social values which shape the saliency of these beliefs such that some are insignificant in influencing judgements while others are crucial?
3. How do those values translate salient beliefs into specific judgements of acceptability or otherwise? (in Durant, 1992:117)

This indicates that raising awareness of values in education requires teachers and students to:

a) identify the values they bring to bear in decision-making (individual and communally held values)

b) examine the beliefs which determine the values

c) question their values and not just accept them

d) decide what sort of values they are e.g. ethical, technical, prudential, religious, moral etc.

Inherent in identifying values will be an understanding of moral principles and ethical positions. But is it possible to identify moral principles if morals are not static but
concepts which are context-related? The issue is:

   a) how can decision-making and action in a given context be understood?
   b) how is this understanding related to the options and consequences of actions
       within a given context and can this understanding be applied to wider, perhaps
       universal contexts?

Context has to be interpreted at a number of levels. This research is concerned with
different areas but always within the framework of science and technology education.
It is also concerned with education at a number of levels. Although school education
may be primarily about the experience of the pupil in the lesson, to exclude awareness
of science and technology in the wider context locally, nationally and globally would
be a major omission.

There are two further aspects arising from the discussion which I may need to address.
The first is concerned with the meanings and differences between the terms facts and
values. An important part of the research will be to try to understand how people
interpret both terms. Second is the acknowledgement that inherent in a discussion of
values, could be moral principles and ethical positions although one could look just at
aesthetic or technical values when ethical or moral values may not arise. Gilligan's
research (1982) on how women make decisions indicates men and women bring
different values to the process. Such gender differences will be an issue in the
research. Recalling the discussion in the introduction - that technology is the main
context for investigating valuing - the nature of technology is now discussed.
"I think we have reached the end of the science-based society that began with the Renaissance. The world view offered by Newton and Descartes was mechanistic. Nature's secrets were knowable. Moreover they were usable. Science moved from being the pursuit of wisdom...to being used to manipulate our environment and ourselves. For 400 years that view of humanity's relationship to nature has predominated and has fuelled the view of progress that has mercilessly exploited nature. Science has provided the underlying power structures of societies." (Tomlinson, 1989:16)

2.0 Defining Technology

Although technology is a pervasive part of today's society there is considerable confusion about what technology actually is.

Technology is a sine qua non of the progress of civilisation yet few people understand technology. (Archer, 1991)

No social, human, or spiritual fact is so important as the fact of technique* [technology] in the modern world. And yet no subject is so little understood. (Ellul, 1965:3)

[* By technique Ellul means far more than machine technology, it refers to any complex of standardized means for obtaining a predetermined result.]

Technology has become a "catchword with a confusion of different meanings" (Pacey, 1983:3).

Many definitions have been offered:

A disciplined process using resources of materials, energy and natural phenomena to achieve human purposes. (Black and Harrison, 1985:3)

Technology is, and always has been, about the realisation of appropriate solutions to human problems, problems which arise in every sphere of human activity. (Thompson, in Head, 1989:1)
Technology refers to a complex range of techniques, organisations and knowledge in addition to tools, machines and utensils. (Monsma, 1986: 11)

[Technology is] a form of cultural activity devoted to the production or transformation of material objects, or the creation of procedural systems, in order to expand the realm of practical human possibility. (Hannah and McGinn, 1980: 27)

Technology is a form of human cultural activity that applies the principles of science and mechanics to the solution of problems. It includes the resources, tools, processes, personnel, and systems developed to perform tasks and create immediate particular, and personal and/or competitive advantages in a given ecological, economic, and social context. (Bush in Rothschild, 1983: 1)

Technology is the conscious and systematic manipulation of one's environment for the purpose of reducing one's dependence on environmental factors for survival. (Gearhart in Rothschild, 1983: 171)

Humankind's collected knowledge about tools of every sort; about the way they work; and about where and how to use them, is what we call Technology. (Archer, 1991: 2)

Technology refers to the organized systems of interactions that utilize tools and involve techniques for the performance of tasks and the accomplishment of objectives. (Rothschild, 1983: 155)

Technology is the application of scientific knowledge to practical tasks by organizations that involve people and machines. (Naughton, in Cross and McCormick, 1986: 3)

From such definitions common features can be discerned, thus technology:

- is concerned with human purposes and possibilities;
- produces objects, goods and services;
- is a cultural activity;
- includes resources such as knowledge, skills, procedures, processes, systems, materials, energy, personnel and tools;
- is a disciplined, rationalised process;
- has a relationship with science.

2.1 Science and Technology

The history of science and technology indicates a symbiotic or synergistic relationship which cannot be separated from the development of human civilisation. Throughout history scientific knowledge has been used in technology and technology has been used to generate scientific knowledge. Boyle et al (1986) identify three significant periods of this mutual development: first the scientific revolution of the seventeenth century, when past dogmas were examined and rejected and fresh theories produced. Galileo, Descartes, Boyle, Harvey and Newton were the giants of this period. The authors suggest that the scientific theories had little impact on ordinary people of the time. The second period was the Industrial Revolution 1750-1850 when the use of water and steam power transformed working life; traditional cottage industries declined with the growth of factories.

Scientific research was reorganised. The "amateur natural philosopher" was replaced by teams in universities. Technology became less and less craft based and more and more science based. The authors call the third period 'Big Science and Technology'. This started in the mid-nineteenth century and continues to the present day. The period is typified by the growth in content and change in context within which scientific work is carried out. From being an interest for a few thousand people it has become central to modern industrial society. The authors believe there is evidence that classical "pure" science research has gradually been replaced by "applied" research (Boyle, Wheale & Sturgess, 1986).

The increase in applied scientific research is inseparable from technology and from the production of goods. Science is not to be concerned with 'bread winning' although for O'Hear (1985) the prestige of science has much to do with technology. Allport also suggests that the authority of science derives from:
technological success and the power derived through it which have mainly impressed politician and public alike. (Allport, 1991:55)

For Polanyi pure science is concerned with furthering knowledge, while applied science is concerned with the market place (Brownhill, 1969).

Layton (1992b) believes that the scientific and technological communities have different aims and that they place value on different approaches. Scientists by processes involving abstracting, analysing and observing, attempt to explain phenomena and to generalise from their observations and explanations. Technologists on the other hand design, make, create and synthesise to produce particular artefacts, systems and processes. Products are judged in terms of efficiency, effectiveness and profitability.

Technological and scientific knowledge is not in the same form. Basic scientific knowledge is translated into a different code, it is converted into a form which makes sense in a world which has different values. Layton also notes that much technology is concerned with improvement and modification and new uses for artefacts. This can be compared with Kuhn's 'normal' science. Radical innovation in technology is analogous to Kuhn's revolutionary science when scientific knowledge provides the push for this innovation (Layton, 1992b).

2.2 Science and Technology Education

Referring to the introduction of National Curriculum Design and Technology in England and Wales, Fensham believes there is evidence that the emergence of technology education is due to frustration with the slowness with which science education was reforming itself and cites government investment in the Technological and Vocational Initiative (TVEI) as evidence for this. However this begs the question: "Why reform science education?" He believes that science and technology education for all children is a response to the "two contemporary imperatives in industrialised countries that link science and technology - economic development and damage to the local and global environment" (Fensham, 1990:14).

Science and technology are separate areas of the school curriculum. Whether the two
subject areas have been taught separately is debatable, for science has always included technological, or at least industrial applications of scientific knowledge. Similarly it is difficult to say how often science concepts are taught in school technology. Until the introduction of the National Curriculum, technology in school was mainly Craft, Design and Technology (CDT) and Domestic Science/Home Economics. Both subject areas were craft based, hence developing practical skills was the main concern.

Since the introduction of the National Curriculum the relationship between science and technology has been much re-examined and debated. Questions are asked such as: Should science be seen as a resource for technology? What of the independent status of science? Should technology provide input into science?

2.3 Design and Technology
The introduction of National Curriculum Design and Technology also stimulated discussion about the role of design in technology. The Technology working party identified five areas of the curriculum which were to be brought together under the 'umbrella' of technology. These are Craft, Design and Technology, Home Economics, Art and Design, Business Studies and Information Technology. The 'terms of reference' to the working party for Technology talked of two vital areas of the curriculum, Design and Technology (Baker, 1988). The skills and knowledge required in Art and Design are seen to be different from those required in the other four areas yet all are interdependent.

The range of design skills include the important cognitive skills of 'imaging' and of 'modelling' which are central to the development of concepts and the communication of ideas (Standen, in Budgett-Meakin, 1992), and yet the design method is a pattern of behaviour employed in inventing things of value which do not yet exist (Gregory, 1967). Pupils need to be educated in aesthetic awareness, psychological understanding and technological skills to enable them to take action in shaping future physical and the social environments (The Royal Fine Art Commission Education Trust, 1987).

Design involves making decisions about people's lives:
It determines how and when we travel, how we clean out fridges, vacuum our floors, and when we pay our debts. In this sense, technology is political and along with social, cultural and economic factors, is an integral part of technological design. (Mulberg, 1991:3)

Design necessarily involves making decisions based on values.

2.4 Technology is value-laden

If it were possible to have objective science, i.e. to have 'pure' science completely separate from any practical use of the knowledge, then the objective scientist would presumably be isolated from any decisions regarding the use of such knowledge. He or she would have no social or moral responsibility regarding the application of the science. By its very nature technology cannot be viewed in the same way for technology is always purposeful.

Technology is a cultural activity, it is an inherent part of human experience, one of the fundamental attributes of human beings in that:

through their ability to make and use tools ...men and women have been able to penetrate and explore their environments; to discover and employ the resources of the natural world; and to create the conditions under which there is time and resource to form, cultivate and express personal, social, cultural and aesthetic values. (Archer, 1991:1-2)

Archer seems to imply that technology provides time to formulate and examine human values, but these values are part of the technological activity itself. The view of technology as "essentially amoral, a thing apart from values, an instrument which can be used for good or ill cannot be supported" (Buchanan, 1962:163).

Pacey illustrates this by linking the snowmobile, a type of motorised toboggan, with life styles. The snowmobile is used for leisure purposes in ski resorts and also as a working
machine by eskimos.

Whether used for reindeer herding or for recreation, for ecologically destructive sport, or to earn a basic living, it is the same machine. (Pacey, 1983:2)

Although the basic machine may be culturally neutral, the web of human activities and the image presented by the machine are not. The streamlining, flashy decoration on the machine and the way it is advertised by fit, handsome, young men, is an image which does not fit with that of the Eskimo people in the Arctic experiencing mechanical failure and fuel problems in the extreme cold. Eskimos have to modify the machines before they are useful and reliable in such extreme cold.

In both science and technology the application or practice of the knowledge and skills is value-laden; practice which involves organisation, planning, management and administration and is influenced by personal and individual experiences. In this sense practice is broad and comprehensive as illustrated in Figure 2.1:

![Diagram](image_url)

Figure 2.1. Diagrammatic definitions of 'technology' and 'technology practice' (Pacey, 1983)
Pacey compares technological practice with medical practice. Medical practice is a general term which may refer to the whole activity of medicine; medical science on the other hand is reserved for the more technical aspects. The analogy between technology and medicine is further expanded in the following chart.

**Figure 2.2**

<table>
<thead>
<tr>
<th>TECHNOLOGICAL PRACTICE</th>
<th>MEDICAL PRACTICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>The organisation to use knowledge and skills for human purposes.</td>
<td>The organisation to use knowledge and skills for treating patients.</td>
</tr>
<tr>
<td>Technical Knowledge and skills.</td>
<td>Technical knowledge and skills.</td>
</tr>
<tr>
<td>The motivation, values and experience of the people involved.</td>
<td>Medical personnels’ sense of vocation, personal values and satisfactions.</td>
</tr>
</tbody>
</table>

Ethical considerations.

Within hospitals the knowledge and skills are the same the world over, what varies is the context in which the knowledge and skills are used. Similarly technological knowledge and skills will be universal. Pacey thus defines technology as:

> the application of scientific and other knowledge to practical tasks by ordered systems that involve people and organizations, living things and machines. (Pacey, 1983:6)

He believes training in science and technology tends to focus on general principles.
Using the example of hand-pumps for developing countries designed and made without thought for the maintenance or management of the use of the pumps he notes that organisation and culture - the human aspect of technology - cannot easily be reduced to general principles. Focusing on scientific and technical principles means:

the wider aspects of technology-practice have come to be entirely forgotten. Thus behind the public debates about resources and the environment, or about world food supplies, there is a tangle of unexamined beliefs and values, and a basic confusion about what technology is for. (Pacey, 1983:8)

Borgmann (1984) sees the purpose of technology in modern western culture as making commodities available to people in a way that is instantaneous, ubiquitous, safe and easy. One way this is achieved is by hiding, as far as is possible, the machinery of the technological device. With little appreciation of the processes of production the device makes little demand on people’s skill, strength or attention. Ends are separated from means. Disburdened from the processes of technology, people become merely consumers of technology. Faced with these factors Borgmann suggests that one way we try to find our bearings is by raising the question of values in relation to technology but notes that because the question is raised within the framework of technology, the choice of values is trivialised. Discussion centres on ends (commodities) and ignores means i.e. the framework of technology and technology itself is devalued:

Not only the machinery of technology and the work out of which it grew are being demeaned through the kind of consumption that is typically final and central today. There is a related degradation of commodities too. (Borgmann, 1984:247)

The way forward for Borgmann is to ‘prune back the excesses of technology and restrict it to a supporting role’. He is not hankering for pretechnological times and past technologies, nor is he anti-technology, he calls for an affirmative and intelligent acceptance of technology which is part of what he terms ‘metatechnology.’

An important part of genuine world citizenship today is scientific and technological literacy. Here too one may hope that an appreciation of the force of technology, nourished by metatechnological practices, would inspire the
attention and dedication that are needed to appropriate the scientific and engineering principles on which the technological machinery rests. Neither the resentful, if dutiful, service to the technological machinery that we discharge in labour nor the distracted pleasure of consumption are conducive to the study of technology. But the voluntary discipline that one exercises in a focal practice, the sustained appreciation of technology, and the desire to join the two in order to regain the cosmopolitan franchise may be helpful to the pursuit of scientific and technological education. (Borgmann, 1984:248)

In arguing for a less restricted meaning for technology, Borgman’s metatechnology may be compared with Pacey’s technological practice.

2.5 Technicism
Throughout history the progress of technology has been identified with inventions or technical advances. Linear, smooth, steadily rising graphs are often used to represent technical progress over time; graphs which conceal ambiguities and smooth out irregularities (Pacey, 1983). The implication is that technical rationality is independent of human affairs.

Technical progress today is no longer conditioned by anything other than its own calculus of efficiency... In technique [technology], whatever its aspect or the domain in which it is applied, a rational process is present which tends to bring mechanics to bear on all that is spontaneous or irrational...this excludes spontaneity and personal creativity. (Ellul, 1965:74-79)

For example workers are deskilled and we have a "system which sees human labour as interchangeable parts" (Braverman in Pacey, 1983:23). Technical determinism is inevitable technological development which drags human society along in its wake. Technicism is an ideology based on techne (technical knowledge) and is the deliberate or unintended misuse of such knowledge.

Technicism is a particularly insidious ideology because, being based on scientific and technical reasoning, it lays claim to ‘value neutrality’...the Technicist game of ‘reducing to procedure’- focusing on the procedures in a
technical way which ignores values, implications or consequences of the outcomes, and about which there is little or no debate. (Lally, 1991:17)

Technicism is technology for its own sake which
...reduces all things to the technological; it sees technology as the solution to all human problems and needs...[it] constitutes a new faith, a new religion...it is something people can believe in. (Monsma, 1986:500)

Theologians have commented that this faith in technology leads to a belief that in today's society:
- everyone has a right to a rising standard of material living;
- there is no upper limit to the standard of living that we can achieve;
- man has the wit and the power to control his environment. There may be crises, but science and technology will get us through in the future as it has in the past;
- a rising standard of living means increasing happiness;
- the chief aim of government should be material prosperity. (Montefiore, 1990)

For Newbiggin (1989) technology is producing more conflict not unity, and science as a source of authority is distrusted as is indicated by antinuclear and environmental movements, radical science movements, alternative technologies and fundamental religious and creationist organisations.

Although it is not termed technicism, the same over-optimistic picture of technology is the concern of Elliott:

Our society is in danger of...ascribing to technology a value, a worth, a place in society that is beyond challenge. Technology thus becomes the yardstick by which other features and virtues are measured. Technical efficiency takes priority over aesthetics. Technique takes primacy over the humanity of what technique accomplishes ... the first step in dethroning technology, to chasing it back to its proper place in the order of things, is not to belittle it or detract from its intellectual fascination or its power to set men and women free from
drudgery, but, rather, to erect around it and over it other values and wisdoms that oblige us to see technology in its correct perspective. The great themes of the meaning of life, the redemptive potential of death and suffering, the astonishing insights of artistic intuition, the recovery of a sense of the cosmic scale of the human tragedy and the human comedy, all that in earlier ages different cultures have understood by wisdom, and all that is supposed to be reflected in and mediated upon through religious consciousness - these are the powers that reduce an upstart lust for technique to its proper place. (Elliott, 1988:179)

2.6. Values and the Technology Curriculum

In 1988 the working party for National Curriculum Technology stated:

Pupils should have some understanding of the value options and decisions which have empowered the technological process in the past and which are doing so today... pupils are engaged in making judgements of many kinds, compromise is intrinsic, what is regarded as optimal is determined by the way in which constraints are defined and values assigned priority. (Interim report, 1988:3ff)

In the Technology Statutory Order (1990) valuing is including in the programmes of study and the Attainment targets. Attainment target 1 states that pupils should identify needs and opportunities but the difference between needs and opportunities is not clarified. Appreciating the difference between needs and opportunities is only one aspect of the valuing inherent in technology.

Under the heading of ‘satisfying needs and addressing opportunities’[ the programmes of study state] ‘pupils should be taught to recognise a variety of forms resulting from people’s different values, cultures, beliefs and needs’, to recognise economic, moral, social and environmental factors can influence design and technological activities and recognise potential conflicts between the needs of individuals and society.’ Needs have to be understood and evaluated before they can be addressed...this ability will only be fostered if pupils are given the opportunity to examine and discuss the basis on which the judgements are made that define goals and determine criteria ... values issues are deeply
bound up with development of the personal qualities and interpersonal skills required for creative activities and constructive team work. (Conway, 1990:22)

Taking part in designing and making in technology requires individual and communal decision making based on values. If one reads documents such as the Engineering Council Report (Smithers and Robinson, 1992) it would be possible to think there is consensus not only on the human problems to be tackled and the human purposes to be pursued but that technology provides a proven route to solutions that will be recognised as appropriate and successful. But the fundamental questions lurking in the background could easily be missed: What belief about human life and purpose lies behind our choice of worthwhile activity? How do we define progress? By what criteria is a solution ‘appropriate’? (Riggs & Conway, 1991:31)

Similarly Layton notes "Value judgements, reflecting peoples' beliefs, concerns and preferences, are ubiquitous in design and technology values and value judgements." He then identifies the wide-ranging nature of these values:

<table>
<thead>
<tr>
<th>Category</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>Right materials for the job, improved performance of artefact, 'neat' solution.</td>
</tr>
<tr>
<td>Economic</td>
<td>Thrifty use of resources, maximising added value of a product.</td>
</tr>
<tr>
<td>Aesthetic</td>
<td>Pleasing to handle, attractive to look at.</td>
</tr>
<tr>
<td>Social</td>
<td>Equality of the sexes, regard for the disadvantaged and handicapped.</td>
</tr>
<tr>
<td>Environmental</td>
<td>Ecological benignity, sustainable development.</td>
</tr>
<tr>
<td>Moral</td>
<td>Sanctity of life.</td>
</tr>
<tr>
<td>Spiritual / Religious</td>
<td>Commitment to a conception of humans and their relationship to nature.</td>
</tr>
</tbody>
</table>

(Layton in Budgett-Meakin, 1992a:36)
Using specific examples Layton explains that value conflicts lie at the heart of much design and technology activity as does resolving these conflicts.

Bearlin believes that teachers need to be aware of value conflicts and mentions awareness of political, economic and social structures of decision-making in science and technology so that questions can be asked such as:

Who establishes priorities for research and development? How participatory and accountable are such bodies? How can we account for the division of labour on gender, class and ethnic lines in scientific power structures? (Bearlin, 1987:3)

This need to make explicit the power structure linked with science and technology is echoed by many feminist writers.

Science is intimately tied to the whole military - industrial complex that is dedicated to preserving its own powerful position, politically, economically, socially, culturally and ethically. Unless steps are taken to recognise these dangers, to examine the values bias of science and to critically question its normative role, and to ensure that the formal education system educates the moral as well as the intellectual capacities of the human being, the scientific dream for a better world could well become not merely a nightmare but the end of human survival. (Burns cited in Bearlin, 1987:7)

2.7 Summary
Since the introduction of National Curriculum Technology, various bodies have offered their perceptions of technology. This has led to a deeper understanding of technology yet there is still confusion about the aims for technology education. There is continuing criticism of current practice:

Technology in the national curriculum is in a mess. What has emerged seems to be very different from what was intended. Her Majesty’s Inspectors are reporting that the standard of work in secondary schools, where national curriculum technology has been running for five terms, is actually declining...Many of the difficulties seem to be associated with a progressively generalised and abstract notion of ‘technology’. (Smithers & Robinson, 1992:5)
However the values which lie behind such criticism and the beliefs which lie behind pressure for change are often assumed, are implicit and are not open to examination. The Engineering Council document (Smithers & Robinson, 1992) made recommendations which seem to have been followed in the revised Technology Orders (NCC, 1993; SCAA, 1994). Although there are opportunities for reflecting on context, prioritising and balancing benefit with harm, I believe these have been downgraded when compared with the original Order. If I were to assess the belief system which lies behind the Engineering Council concerns and the proposed changes, I would suggest it has strong elements of technicism.

Technology educators have, I believe, a right to know the parameters in which they are working. Political and professional bodies who have power should be explicit about their expectations and the framework of interpretation from which they work. After mountains of paperwork, heated debate, much speculation and rumour we are no nearer clarifying and justifying the reasons for including technology in the curriculum of all pupils 5-16 years than in the optimistic early days of the National Curriculum:

We may be no nearer to articulating and delivering what is actually required than were those concerned with the technical schools some thirty years ago...Much has changed in the structure of state education since then, but one can only guess at the extent of any shift in the underlying philosophy and values of the curriculum. It is disturbing to contemplate the creation of City Technology Colleges, the extension of the Technical and Vocational Initiative and [National Curriculum Technology] without any coherent understanding of what technology implies or what it has to offer pupils.

(Thompson in National Curriculum Science, 1989:1)

What was obvious in the proposed 1993 Technology Order (NCC,1993) and still is, to a lesser extent is a greater emphasis on science, actually on physical science. The policy makers, and those teaching technology, need to be challenged to make explicit their beliefs about technology and its relationship with science. In saying this I cannot assume however that there is consensus about the nature and status of science. This needs to be explored.
"Man's respect for knowledge is one of his most peculiar characteristics. Knowledge in Latin is scientia, and science came to be the name of the most respectable kind of knowledge. But what distinguishes knowledge from superstition, ideology or pseudoscience? The demarcation between science and pseudoscience is not merely a problem of armchair philosophy; it is of vital social and political relevance." (Lakatos: Open University radio lecture 1973)

3.0 A Historical Review

The first humans who observed, experienced, described and recorded their surroundings were acting as scientists. Edelstein suggests that the emergence of scientific knowledge (the knowledge of mathemata or epistemai, or scientiae) was a discovery of a relatively late period of history, the seventh or sixth centuries BC "when for the first time an attempt was made to give a consistently rational picture of nature, to establish a limited number of principles and to deduce their consequences" (Edelstein in Crombie, 1963:15).

In saying this he implies that to be science, there has to be an identified methodology which is linked in some way with mathematics. Bronowski (1977) believes that astronomy was the first science and that this became a model for all other sciences because it could be turned into exact numbers. Astronomical calculations were carried out and recorded on clay tablets in 3800 BC by Chaldean priests of Mesopotamia (Koestler, 1959). South Asian tribes developed an astronomy based on the observation of the moon. Vedic culture (which began in 1500 BC) required priests to perform sacrifices at auspicious times, therefore calendars had to be developed, possibly because "the Vedic period possessed mathematical knowledge of a relatively high order, including a knowledge of numbers up to 10 million million" (Goonatilake, 1984:6).

In these early times Chinese mathematics were comparatively advanced.

Decimal place-value and a blank space for the zero had begun in the land of the Yellow River earlier than anywhere else. (Needham, in Crombie, 1963:118)

Although practical mathematical calculations developed in Babylon, China and India,
modern mathematics and science is generally thought to have started in sixth century BC in Greece. Ionian philosophers developed the mathematical natural sciences: statics, hydrostatics, acoustics and theoretical astronomy.

For the first time mathematics was conceived of as a science. Arithmetic and geometry were transformed into great deductive systems. The structure of deduction was subjected to a special logical examination, the science of logic made its appearance. (Yushkevich in Crombie, 1963:293)

This was the time of Pythagoras, Archimedes, Plato and Aristotle. The centuries between 600 and 300 BC have been termed the heroic period of Greek science; an heroic period which influenced Western science for nearly a millennium and a half. At the end of the Dark Ages, in the seventeenth century, came the beginning of the scientific revolution, a time for:

novel thoughts and concepts, for illumination in the light of which many dogmas from the past were examined and rejected, and fresh teachings hammered out to take their place. (Boyle, Wheale and Sturgess, 1986:14)

This was the time before the Age of Reason or Enlightenment in the eighteenth century. From this time science developed through the work of Copernicus, Kepler and Galileo, Descartes and Newton in the sixteenth and seventeenth centuries, to Rutherford, Einstein and Crick and Watson in the twentieth. Throughout this time mathematical knowledge and scientific knowledge developed often synergistically.

3.1 Logic and Deductivism
Mathematics and science emerged in early Greece as a result of logic and deductive systems. Pythagoras found that for any right angled triangle the square on the longest side is equal to the sum of the squares of the other two sides. Using a variety of right angled triangles the theory can be shown to be true; it can be proved. Using the theorem it is then possible to deduce the length of a side of a right angled triangle given the lengths of the two other sides. Such logical reasoning and proof is the stuff of mathematics.
For example

\[ x + y = 16 \]
\[ x = 10 \]

\text{conclusion}
\[ y = 6 \]

It is clear that the reasoning in the above example is correct for \( x + y = 16 \) and \( 10 + 6 = 16 \), the reasoning is valid. But can this method of reasoning be applied to science? In the following example the same method of reasoning is applied.

All birds with wings can fly.
Penguins are birds and have wings.

conclusion: Penguins can fly.

In this case the reasoning is valid but because the premise is incorrect i.e. that 'all birds with wings can fly' the reasoning has misled; the process of deduction has produced an incorrect conclusion. Only if the premise is true can the conclusion be valid and true, in this case the statement that 'all birds with wings can fly' is not true. Deductive reasoning "constitutes the discipline of logic...Deductive reasoning [and hence logic] does not act as a source of true statements about the world"(Chalmers, 1978:6).

Logic is concerned with the structure of reasoning, not with facts. Deductive reasoning is concerned with deriving statements from other statements. A statement about the properties or behaviour of one particular object or situation (or a limited sample of objects or situations) is obtained by simple rules of logical thinking from a statement covering the whole class of objects or situations to which the one under consideration belongs. Deduction only specifies or applies the consequences of a general statement to one particular object included in the world class to which the general statement refers. Deductive reasoning is safer than inductive reasoning. Provided the initial general statement is true, the deduction from it is also true (Brown et al, 1986).

Science is more complex than this, somehow observation and experience are involved.
The penguin example above could be refuted or verified by observing penguins for some time or by dropping them over a cliff. An argument may be valid yet have nothing to do with truth; deductivism alone is inappropriate as an explanation of scientific reasoning. Deductivism as a method, that is, if only deductive reasoning is used, does not lead to new knowledge although it does add to knowledge. If one relied only on deductive reasoning without experiment or observation, there would be no understanding that some birds do not fly. Deductivism only applies and explains the consequences of the initial general statement as they apply to one individual case. This is too restrictive as an interpretation of scientific method.

3.2 Inductivism

The basis of truth for an inductivist is not logic but experience. Inductivism starts with evidence which may be acquired by observation and from the evidence laws or theories may be produced. Mendel's Laws of Heredity are an example of inductive reasoning. Mendel counted the number of pea seeds and plants with particular characteristics over a number of generations and found particular ratios between the characteristics e.g. 3:1 in the first filial generation.

From the results he obtained after carefully growing plants so that pollination was controlled, he formulated the following as his first law:

An organism’s characteristics are determined by internal factors which occur in pairs. Only one of a pair of such factors can be represented in a single gamete.

The essence of inductivism is outlined in the principles of John Stuart Mill's Canons: principles with which philosophers William of Ockham and Herschel agree.

The Canon of Agreement: If two or more instances of the phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree is the cause (or effect) of the given phenomenon.

The Canon of Difference: If an instance in which the phenomenon under investigation occurs, and an instance in which it does not occur have every circumstance in common save one, that one occurring only in the former, the
Looking for the common circumstance in a number of investigations which result in the same observation, can only be part of the story. For example Mendel thought that the presence of both wrinkled and smooth seeds in the second generation, was due to differences in the parent plants. All parent plants, (from seeds from the same plant all planted at the same time) produced similar ratios of wrinkled and smooth peas, thus by agreement the phenomenon of seed coat appearance is explained by the parental generation. Another observation could be carried out with plants grown from smooth seeds from parental plants which had themselves been grown from smooth seeds. If this cross produced all smooth seeds with no wrinkled seeds, then by the canon of difference the hypothesis that the parental plants determine the appearance of the second generation seems again valid. However in both cases factors other than parental contribution are being ignored. For example no mention is made of possible differences in the amount of water given to the plants and inadequate watering when the seeds were maturing might have produced wrinkled peas.

In science lessons children are taught to bear in mind the need for fair tests or controls in scientific investigations: this parallels Mill's second canon that of having every circumstance in common except the one to be investigated. In the case of Mendel's peas, controlling the amount of water alone will not do. What of temperature, soil, water? To be able to control conditions the mechanism of plant growth has to be understood; a theory of plant growth is needed. Without a theory the phenomenon to be investigated and the control of circumstances will be difficult if not impossible to determine. This seems to be a chicken and egg situation, therefore it is not feasible to say:

\[
\text{By Induction} \\
\text{Facts acquired} \rightarrow \text{Laws and Theories} \quad \text{through observation}
\]

for without the theory it may not be possible to see or identify the facts. This is illustrated by histological examinations when particles in cells may be overlooked during
microscopic examination of tissue for the presence of bacteria. If a theory exists that in
the presence of certain bacteria particles will be present, then the particles will be
observed. This is a simple illustration, but it suggests that the theoretical background
can influence the process of observation.

Whether any particular application of Mill’s Canons yields information of value
is determined by how good a theory we have to explain the processes we are
investigating. (Harre, 1972:41)

But what of using this reasoning to formulate theories when the observations are based
on coincidences or errors in experimental techniques? As discussed earlier, logical
arguments are true only if the premise is true. In the histological example the particles
in the cells might have come from the stain used to colour the bacteria.

Mill’s two Canons of Agreement and Difference seem to provide a basis for justifying
the belief that Mendel was following an inductive method of reasoning. By collecting
numbers which were concerned with similarities and differences, Mendel found that the
pattern for the ratios of seeds was repeated year after year. Using the numbers as ratios
Mendel successfully used inductive reasoning to produce his Laws which he then used
to make predictions about future generations. There are many accounts of successful
explanations and predictions made possible by apparently inductively derived laws.

3.3 Inductivism: An Analysis.
Commonality of circumstances as an explanation for cause or effect as outlined in Mill’s
Canons is a limited form of reasoning, but theories are often used at the start of an
investigation. In fact Harre states that the Canons have been promoted as a complete
theory of science - a theory which can be expressed in three principles:

The Principle of Accumulation: that scientific knowledge is a conjunction of
well-attested facts, and that such knowledge grows by the addition of further

well-attested facts, so that the addition of a new fact to the conjunction leaves
all the previous facts unaltered.
The Principle of Induction: that there is a form of inference of laws from the accumulated simple facts, so that from true statements describing observations and the results of experiments, true laws may be inferred.

The Principle of Instance Confirmation: that our belief in the degree of plausibility of (or our degree of belief in) a law is proportional to the number of instances that have been observed of the phenomenon described in the law. (Harre, 1972:42)

The methods Mendel employed seem to be in line with the last two principles; from his observations he apparently recorded facts about pea plants and used these facts to infer laws. Mendel carried out observations on 21,000 plants, presumably a sufficient number to ensure plausibility.

In 1866 Mendel published his paper relating to the particulate nature of inheritance. At the time of publication the understanding of inheritance might be summarised thus:

It had long been known that the characteristics of organisms can be shuffled and recombined ... and several earlier plant hybridizers had emphasized the point in discussions of hybrids. However, this was thought of as a recombination of characters, not of discrete germinal elements. The usual interpretation of heredity involved some form of the idea of a mixing of fluids at fertilisation, as supposed by Aristotle and Kolreuter. On that theory the contributions from remote ancestors were gradually and regularly diluted in successive generations, but could still come to expression in occasional individuals. (Sturtevant, 1966:11)

In 1868 Darwin postulated a theory of pangenesis involving hereditary 'gemmules' that were transmitted at sexual reproduction but he had no clear idea of the difference between germ cells and somatic cells (Dowdeswell, 1984:49). Gemmules budded off from all tissues of the organism and were carried in the blood to the reproductive organs. Darwin's theory of inheritance involved the progressive dilution and loss of characteristics due to blending (incidentally a notion at odds with his theory of natural selection). His hypothesis was never widely accepted (Huxley and Kettlewell, 1965). Although not accepted by the scientific community Darwin's pangenesis theory was the
forerunner of the particulate theories of Weismann, Galton and de Vries and others developed before 1900 (Sturtevant, 1966).

The theories of inheritance prevalent in the mid-nineteenth century were not based on experimental observation. Galton and his associates dominated genetic studies. They were concerned with biometric studies, ie statistical studies of resemblances and differences between organisms and attempts to correlate such variables. This is illustrated by Galton’s interest in transmission of traits such as ‘genius’ in families as outlined in his book ‘Hereditary Genius’ published in 1869. The significance of Mendel’s work was not realised until thirty-four years after its publication (Dowdeswell, 1984). It is sometimes said that the climate was not right for understanding Mendel’s work. Theories in existence in the mid-nineteenth century required blending and consequent dilution of variations in characteristics. Mendel’s statement that genetic factors do not blend but remain distinct and uncontaminated was therefore contradicting existing theory. At the time of publication Mendel’s ideas were not added to the well attested facts and therefore had no impact on the previous facts.

Only with the rise of interest in the ‘particulate theory’ of inheritance - for example Weismann’s germ plasm theory in 1892, was the climate right for appreciating Mendel’s work. The first of the three principles of inductivist theory, namely that science grows by accumulation of facts, neglects the role of theory. We might see Mendel’s method as inductivism but the acceptance or non-acceptance of his work was dependent on comparison with existing theories or hypotheses. It is also interesting to speculate on the part played by the differing methods of investigation in operation. A statement about the inference of laws from observed facts says nothing of the approach and the way the observation is carried out. There is a clear contrast between Mendel’s direct observation of living plants and seeds, Galton’s statistical techniques and Darwin’s theorising.

Inductive methods are those which take singular statements obtained from results of observations or experiments and use these statements to produce theories which have universal relevance. As a complete method inductivism is untenable. This will become
clearer as the objections to inductivism are examined.

3.4 Objections to Inductivism

The inductivist view of science is held by many, particularly those not engaged in scientific research (Harre, 1972). Chalmers believes holding this view has merits because it gives a formalized account of some of the popularly held impressions concerning the character of science, its explanatory and predictive power, its objectivity and its superior reliability compared with other forms of knowledge. (1978:10)

Its objectivity derives from its dependence on observation and inductive reasoning with no acknowledgement of theorising and hypothesising. The observer sees the object, or environment, or reaction and believes these to be external to him or herself and assuming this to be so, then many observers will be able to ‘see’ (have knowledge of) the observation in the same way, for the observations are independent of the observer. Thus observational statements are reliable because of the concurrence of others by direct use of the senses.

Consider again the work of Mendel. The assumption could be that anyone repeating the processes of growing, pollinating, harvesting and counting seeds in exactly the same way that Mendel did will make the same observations and by inductive reasoning will come to the same conclusions. This is a false assumption for the process takes no account of Mendel’s thinking and insight.

The realisation of the importance of theory in the scientific process has a number of consequences. One must ask if there can be such things as scientific facts, i.e. facts which are immutable scientific truths.

It is not true that science grows by an accumulation of facts. The growth of science is a leap-frog process of fact accumulation and theoretical advance. A change in theory can turn seeming facts into falsehoods. (Harre, 1972:43)
If scientific facts exist then they must be independent of theory and the only facts independent of theory are presumably observations i.e. are stimuli for the senses. The implication is that scientific facts are those perceived by the scientist using his or her senses. But as Harre says these ‘facts’ which the individual scientist experiences are not public facts:

they are private and do not form part of the public domain of knowledge; if they are public facts they are affected by all sorts of influences particular from previous knowledge and upon which their exact form and our confidence in them depend. At least for science, there are no brute facts. There are no facts which other facts may not change; there is no knowledge altogether independent of theory. (Harre, 1972:43)

Two observers viewing the same object may observe different aspects. Light rays may even strike the retina in exactly the same way in both cases, triggering identical impulses along the optic nerve to the brain yet what is ‘seen’ may be interpreted in different ways. There is a subjective element, which thus raises questions about the fallibility of evidence acquired by observation. Interpretations of observations are influenced by the individual’s experiences; experiences which vary with expectations and knowledge. Yet it is clear that individuals do see and are able to describe the same objects; there is stable, shared knowledge. Consensus about observations is possible in some degree but not completely or totally.

If doubt is expressed about the ability to obtain consensus because perception of instances is based on experience, then this in turn raises doubt about the relevance of the quantity of observations carried out. The third principle, that of instance confirmation, becomes questionable if not invalid. This may be illustrated by considering a large number of instances when the same data is collected. From the same numerical data it is possible to infer more than one conclusion, conclusions which may be mutually incompatible. The inferences the scientist makes about the data will depend on the theories he or she holds; theories which may be fallible.

3.5 Hume on Inductivism
Hume pointed out that if induction is based on experience then it is relying on inductive methods to make generalised inferences. He illustrated this by the move from - 'All known X’s are 0 to All X’s are O'... That there are no demonstrative arguments in this case seems evident, since it implies no contradiction that the course of nature may change and that an object, seemingly like those we have experienced, may be attended with different or contrary effects. The alternative is a premise regarding ‘matter of fact and real existence’...But...we have said that all arguments concerning existence are founded on the relation of cause and effect, that our knowledge of that relation is derived entirely from experience, and that all our experimental conclusions proceed on the supposition that the future will be conformable to the past. So to try to prove that proposition itself in this way ‘must be evidently going in a circle and taking that for granted which is the very point in question'. (Flew, 1961:70)

No matter how numerous the observations, from the experimental evidence it is impossible to extrapolate to all future (relevant) circumstances. All that can be said is ‘All known X’s are 0’. Hume’s acknowledgement of the subjective dimension in inductive thought and of theorising is indicated by statements such as ‘the influence of volition over the organs of the body’ and ‘the act or command of our will’ in thinking (Flew, 1961:109). For Hume ideas are always mental images, perceptions of the mind which arise from experience.

In all single instances of the operation of bodies or minds there is nothing that produces any impression, nor consequently can suggest any idea, of power or necessary connection. But when many uniform instances appear, and the same object is always followed by the same event, we then feel a new sentiment or impression, to wit, a customary connection in the thought or imagination between one object and its usual attendant; and this sentiment is the original of that idea we seek for. The new impression, the source of the idea of necessary connection, is the product of the same habitual association. (Flew, 1961:117)

Connections between instances are made in the mind not due to logic but as ideas. The
connections are repeated many times and thus become habitual associations. So empirical belief is the product of habitual association. Science for Hume is inseparable from human nature and therefore it is impossible to conceive of truly objective, scientific experiments.

3.6 Kant on Inductivism

In the preface to the first edition of *Critique of Pure Reason*, Kant says:

My inquiry refers to the intellect in relation to its objects and sets out to demonstrate that its *a priori* conceptions have objective validity. (1781)

Knowledge which is independent of experience he calls *a priori* and that which has its source in impressions (or experience), *a posteriori*. Propositions (theories, ideas) are not conceived from experience and experience cannot impart universality to a judgement.

All we can say is: so far we have not noticed an exception to this rule, so we infer by induction that it may be generally valid and assume its universality. Necessity and universality are the criteria of *a priori* knowledge. (Kant trans Rabel, 1963:105)

Inductivism, universal causation is *a priori* valid, and is not based on empiricism. Kant was not against empiricism, indeed he was critical of great rationalists of his day who thought that

in principle we could establish any facts about the world *a priori*. Not merely did they not understand the importance of experiment, of observation, in enlarging our knowledge of the world, they definitely scorned experimental methods. They believed that empirical observation could only yield a very muddy and inferior picture of the world. (Wilkerson, 1976:5)

However it is worth adding his warning to empiricists:

Now if the empirical philosopher had no other intention than to damp down the arrogance and vainglory of those who boast of possessing insight and knowledge where all insight and knowledge are at an end, if the empiricist confined himself
to this intention, his principle would be one of moderation and modesty. But if the empiricist as he mostly does, becomes himself dogmatic and boldly denies what lies beyond the field of his experience, he too commits the fault of being presumptuous. (Kant trans Rabel, 1963:115)

Wilkerson says that "Kant lacks any appreciation of the importance of inductive techniques in enlarging our scientific knowledge" (1976:126).

Perhaps the inductive techniques Wilkerson refers to are not 'pure' inductivism as defined by Mill's Canons and the Principles derived from the Canons by Harre. It is naive to think modern inductivists take such an extreme position.

None of the modern, more sophisticated inductivists would wish to uphold the literal version of it [inductivism]. They can dispense with the claim that science must start with un-biased and unprejudiced observation by making a distinction between the way a theory is first thought of or discovered on the one hand, and the way in which it is justified or its merits assessed on the other. (Chalmers, 1978:32)

Polkinghorne (1992) however thinks scientists still use inductivism but through their own experience they know how far to go with it. Yet for Popper the various difficulties of inductive logic...are insurmountable. So also I feel are those inherent in the doctrine, so widely current today, that inductive inference, although not 'strictly valid', can attain some degree of 'reliability' or of 'probability'. (Popper, 1959:29)

3.7 Popper and Falsifiability
Popper's discussions with fellow students led him to examine the formulation of theories. Three theories: Marx's theory of history, Freud's psycho-analysis and Adler's 'individual psychology' stimulated his thinking.

neither was it that I merely felt mathematical physics to be more exact than the sociological or psychological type of theory. Thus what worried me was neither the problem of truth,...nor the problem of exactness or measurability. It was
rather that I felt that these other three theories, those posing as sciences had more in common with primitive myths than with science; that they resembled astrology rather than astronomy. I found that my friends who were admirers of Marx, Freud and Adler, were impressed by a number of points common to these theories, and especially by their explanatory power. These theories appeared to be able to explain practically everything that happened within the fields to which they referred. The study of any of them seemed to have the effect of an intellectual conversion or revelation, opening your eyes to a new truth hidden from those not yet initiated. Once your eyes were thus opened you saw confirming instances everywhere: the world was full of verifications of the theory. Whatever happened always confirmed it. Thus its truth was manifest and unbelievers were clearly people who did not want to see the manifest truth; who refused to see it, either because it was against their class interest, or because of their repressions which were still ‘un-analysed’ and crying aloud for treatment. (Popper, 1963:35)

Popper uses two examples to illustrate his dissatisfaction with the theories. The first refers to an interpretation of the same child’s problems using both Adlerian and Freudian theory when the theories offered very different explanations. The second involved Adler’s diagnosis of a similar case from a distance. When Popper queried the validity of such a diagnosis Adler replied he was able to do this because of his thousandfold experience.

In contrast to the psychologist’s theories Popper knew that a theory such as Einstein’s gravitational theory with its prediction that light must be attracted by heavy bodies, was open to verification or refutation (Verification had taken place in 1919 by the British astronomer Eddington with mathematic calculations and photographic observation of eclipses). The crucial point for Popper was that in making such a prediction Einstein could have been wrong. There was a risk in making the prediction. Empirical evidence may not have verified the prediction and so the theory could have been refuted. In contrast the psycho-analytic theories of Adler and Freud were untestable and irrefutable.

Inductivism concerned as it is with derivation of theories from the accumulation of well-
attested facts, with true statements describing observations and the results of experiments, makes no allowance for the 'risk factor'. For Popper there was:

no such thing as induction... Theories are never empirically verifiable. A system can be empirical or scientific only if it is capable of being tested by experience. It is the falsifiability rather than the verifiability which is to be taken as the criterion of demarcation. (Popper, 1959:40)

To be acceptable a scientific proposition must be capable of being refuted. Scientific propositions are modified as a consequence of fresh experimental observation ie because they have been put to the test. Better theories are thus produced because the experimental evidence has led to falsification of aspects of the previous theory.

The acceptance of one particular theory over others occurs because the accepted theory has withstood the severest testing - described by Popper as a kind of 'natural selection' (Popper 1959:108). To be accepted the theory must be testable in a rigorous way and the degree of testability is important in determining its acceptance. For Popper a theory is falsifiable if there is at least one basic related statement which has the potential to falsify the theory and the number of such statements determines the degree of falsifiability.

It might be said that if the class of potential falsifiers of one theory is 'larger' than that of another, there will be more opportunities for the first theory to be refuted by experience; thus compared with the second theory, the first may be said to be falsifiable in 'a higher degree'. This also means that the first theory says more about the world of experience than the second theory, for it rules out a larger class of basic statements... the amount of empirical information conveyed by a theory, or its empirical content, increases with its degree of falsifiability. (Popper, 1959:113)

If the pertinent basic statements forbidden by a particular theory are many (i.e. the empirical content is great) the basic statements not forbidden by the theory will be proportionally few. Such a theory will be easy to falsify since the range of possibilities left for empirical verification is reduced. This is the aim of theoretical science. It aims
at restricting the ‘range of permitted events to a minimum’.

If we could be successful in obtaining a theory such as this, then this theory would describe ‘our particular world’, as precisely as a theory can; for it would single out the world of ‘our experience’ from the class of all logically possible worlds of experience with the greatest precision attainable by theoretical science. All the events or classes of occurrences which we actually encounter and observe, and only these, would be characterized as ‘permitted. (Popper, 1959:113)

Polanyi (1958) argues that scientists generate a vision of the world outside of themselves; they reveal the reality using models which represent reality.

Popper states that he reformulated the conclusions he had first produced in 1919-1920. The reformulations are:

1. It is easy to obtain confirmations, or verifications, for nearly every theory—if we look for confirmations.
2. Confirmations should count only if they are the result of risky predictions; that is to say, if, unenlightened by the theory in question, we should have expected an event which was incompatible with the theory – an event which would have refuted the theory.
3. Every ‘good’ scientific theory is a prohibition: it forbids certain things to happen. The more a theory forbids, the better it is.
4. A theory which is not refutable by any conceivable event is non-scientific. Irrefutability is not a virtue of a theory (as people often think) but a vice.
5. Every genuine test of a theory is an attempt to falsify it, or to refute it. Testability is falsifiability; but there are degrees of testability: some theories are more testable, more exposed to refutation, than others; they take, as it were, greater risks.
6. Confirming evidence should not count (except when it is the result of a genuine test of the theory; and this means that it can be presented as a serious but unsuccessful attempt to falsify the theory.
7. Some genuinely testable theories, when found to be false, are still upheld by their admirers—for example by introducing ad hoc some auxiliary assumption, or
by re-interpreting the theory ad hoc in such a way that it escapes refutation. Such a procedure is always possible, but it rescues the theory from refutation only at the price of destroying, or at least lowering, its scientific status. This discussion can be summarised as the criterion of the scientific status of a theory is its falsifiability, or refutability, or testability. (Popper, 1963:36)

NB Popper later used the word corroboration instead of verification and confirmation.

Thus following Popper, all scientists can do is falsify theories by way of observation and experimentation. People must not be misled into believing a theory to be true by the length of time it has been accepted, and considered to be successful. Neither must they be misled by the number of times it has survived severe testing. Theories are acceptable only as candidates for future testing and eventual overthrowing.

We learn nothing from science that proves or confirms a theory ... For Popper, growth of scientific knowledge,... can only be the growth of knowledge that more and more theories are false. Of those that survive, we can have no justifiable confidence in their truth. Indeed, intellectual honesty demands that we should be looking to falsify them tomorrow, if not today. On this point ... Popper may be nearer the truth than those who blithely assume that survival of tests does increase the possibility that a theory is true. Whether this is so or not, it did seem that we could at least be sure that we were being rational in rejecting falsified theories. (O’Hear, 1985:44)

There is little doubt that Popper’s work can be seen as rejecting blind trust in inductivism, but he was not a naive falsificationist; he acknowledged that counter-evidence could be explained away and he stressed the theory-laden nature of empirical data (Popper, 1963). Popper also realised that theoretically based assumptions were necessary for the growth of scientific knowledge. This is true for Newtonian dynamics which Popper discussed, and for present day cosmologists as is illustrated by Hawking’s description of a theory as a model and a set of rules that relate quantities in the model to observations and that the theory exists only in the mind of people and does not have any other reality. (Hawking, 1988: 9).
3.8 Lakatos on Inductivism

Inductivism has been shown to be inadequate as a complete method for inductivism forbids speculation, yet modern theories of physics are speculative and abstract. Sceptics and probalists require probabilities to be attached to theories and evidence. Science deals in generalisations which cannot be verified but can be falsified as per Popper. Falsifiability is the essential feature of science. Scientific propositions can be tested but metaphysical generalisations and beliefs are untestable.

Lakatos proposes a Methodology of Scientific Research Programmes which allows people to "do their own thing" but only as long as they publicly admit "what the score is" between them and their rivals. He considers elitism the most influential tradition among scientists, the claim being that "good science can be distinguished from bad, or pseudoscience, better science from worse science." (Lakatos, 1978a:111)

Now, Newton’s theory of gravitation, Einstein’s relativity theory, quantum mechanics, Marxism, Freudianism, are all research programmes, each with a characteristic hard core stubbornly defended, each with its more flexible protective belt and each with its elaborate problem-solving machinery. Each of them, at any stage of its development, has unsolved problems and undigested anomalies. All theories, in this sense, are born refuted and die refuted. But are they equally good? (Lakatos, 1978b:5)

Elitists recognise the superiority of the theories of Newton and Einstein over astrology, iridology or radiesthesia or other kinds of pseudoscience. They recognise scientific progress but claim that there is not, and cannot be, a "statute law to serve as an explicit, universal criterion for progress or degeneration. Science can only be judged by case law, and the only judges are the scientists themselves. If these authoritarians are right, academic autonomy is sacrosanct and the layman, the outsider, must not dare to judge the scientific elite." Scientific knowledge is inarticulable, it belongs to the tacit dimension, a dimension which is shared and understood only by the elite. (Lakatos, 1978a:111)

3.9 Hypothetico-deductive Method
Hypotheses are statements of expectations about the things being studied, which are put forward tentatively, usually on the basis of incomplete evidence, as a reasoned guess. The formulation of a hypothesis takes into account all that is already known about the object or situation under investigation and tries to identify or predict as yet unknown but possible features and/or correlations between different parts or aspects of the object or situations (Brown et al, 1986:7).

Hypotheses can arise by intuition or guesswork, Medawar prefers inspiration. He remarks that:

[hypotheses] are the subject-matter of psychology and certainly not of logic and notes that it is wrong to speak of deducing hypotheses, one deduces things from a hypothesis. (Medawar, 1979:46)

The hypothetico-deductive system is explained thus:

First, there is a clear distinction between the acts of mind involved in discovery and in proof. The generative or elementary act in discovery is 'having an idea' or proposing a hypothesis. Although one can put oneself in the right frame of mind for having ideas and can abet the process, the process itself is outside logic and cannot be made the subject of logical rules. Hypotheses must be tested, that is must be criticised. These tests take the form of finding out whether or not the deductive consequences of the hypothesis or systems of hypotheses are statements that correspond to reality. As the very least we can expect of a hypothesis is that it should account for the phenomena already before us, its ‘extra-mural’ implications, its predictions about what is not yet known to be the case, are of special and perhaps crucial importance. If the predictions are false, the hypothesis is wrong or in need of modification; if they are true, we gain confidence in it, and can, so to speak, enter it for a higher examination; but if it is of such a kind that it cannot be falsified even in principle, then the hypothesis belongs to some realm of discourse other than Science. (Medawar 1967:147)

This may be seen as another way of restating Popper’s conjectures and refutations.
Conjectures involve ideas and imagination and formulation of theories and hypotheses; refutations attempt to falsify them. Medawar acknowledges Popper's was the first "strongly reasoned and fully argued exposition of a hypothetico-deductive system" (Medawar, 1967:147) but it was Whewell who first identified the hypothetico-deductive explanation for the way scientists think (Medawar, 1979). Medawar suggests the hypothetico-deductive system "reconciles two sets of contradictory opinions"; sets that are clusters of premises around the notion that science is concerned with facts and the humane arts with ideas (Medawar, 1967:113). He reiterates this in saying that in real life the imaginative and critical acts that unite to form the hypothetico-deductive method alternate so rapidly, at least in the earlier stages of constructing a theory, that they are not so spelled out in thought.

3.10 Positivism

Francis Bacon and other empiricists of the 17th and 18th centuries have been called positivists for they accepted only that which is observable in the world, and without making attempts to find further meanings behind the observable they viewed all genuine knowledge as scientific. In other words theories can only be justified by the extent to which they can be verified by an appeal to facts acquired through observation. Positivists conceive of theories as organised according to the canons of deductive logic, the logic of mathematics and taxonomy. The effect is to force them to conceive very narrowly of theory and its ideal logical structure (Harre, 1972). A scientific theory should be a deductive structure, similar to mathematical reasoning i.e. following the same pattern of logical reasoning.

Positivists see this as the ideal reasoning for the acquisition of any human knowledge.

According to logical positivism a statement is only meaningful if it is either 'tautological' or empirical. (Lakatos, 1976:1)

(However Lakatos also believed that developments in mathematics which have taken place this century have given new logical reasoning new credibility)

In construing knowledge only as that which applies to phenomena which can be sensed, the positivists see science as akin to phenomenalism. There is no possibility of
exploring the world beyond the actual or possible experience and logic and deductivism are justifiable forms of reasoning. Although positivism has generally been disenfranchised by philosophers, science is still thought to proceed in this way by many people.

3.11 Scientific Revolutions
Kuhn is more concerned with the social and psychological behaviour of scientists than are many other philosophers. According to Kuhn, some historians of science wondered if they had been asking the right questions; i.e. questions about when something was discovered and by whom; questions which seemed to be based on the assumption that science develops by accumulation of individual discoveries and inventions. He notes that at the same time as this questioning of the questions, historians were acknowledging the growing difficulties in distinguishing the "scientific" component of past observation and belief from what their predecessors had readily labelled "error" and "superstition".

The more carefully they study, say, Aristotelian dynamics, phlogistic chemistry, or caloric thermodynamics, the more certain they feel that those once current views of nature were, as a whole, neither less scientific nor more the product of human idiosyncrasy than those current today. If these out of date beliefs are to be called myths, then myths can be produced by the same sort of methods and held for the same sorts of reasons that now lead to scientific knowledge. If, on the other hand they are to be called science, then science has included bodies of belief quite incompatible with the ones we hold today. (Kuhn, 1962:2)

Such questioning of the historical perspective leads to doubt about the cumulative process of science and hence to an interpretation of scientific development in the light of the cultural influences and relationships experienced by the scientist at the time. Kuhn argues that these considerations indicated that a new image of science was needed. This new image could not be explained by methodologies alone for a person acting in a scientific manner may reach any one of a number of incompatible conclusions. Reaching a conclusion would likely depend on personal prior experience, accidents in
investigative work and aspects of the individual's personality (Kuhn 1962). Thus Kuhn seems to be suggesting a less empirical and more subjective interpretation of science. 

An indication of this subjectivity is the use of the term "body of belief." "Observation and experience can and must drastically restrict the range of admissible scientific belief, else there would be no science. But they cannot alone determine a particular body of such belief" (Kuhn, 1962:4). In carrying out scientific activities (i.e. during Normal Science: when the bulk of science is done) the members of the scientific community assume they hold the same belief system, one which makes assumptions about what the world is like. The assumptions which are part of this system have to be defended if Normal Science is to be upheld. This requires the suppression of "fundamental novelties because they are necessarily subversive of its (ie Normal Science) basic commitments". Yet there is flexibility in the system, and sometimes the suppression cannot be maintained. Problems are found to be unsolvable by known means and rules or a new piece of equipment reveals an anomaly. When the anomalies are addressed and further investigations undertaken, then a paradigm shift may occur involving a "new set of commitments,[and] a new basis for the practice of science (Kuhn, 1962: 5,6). Kuhn defines such shifts as 'scientific revolutions.'

Scientists sharing a paradigm are "committed to the same rules and standards for scientific practice. That commitment and the apparent consensus it produces are prerequisites for normal science, ie for the genesis and continuation of a particular research tradition" (Kuhn, 1962:11). Without a paradigm or some "candidate for a paradigm", (Kuhn, 1962:15) it will be impossible to assess the relevance of gathered facts for a particular development. Yet the paradigm itself restricts the assessment process. The theories used and the explanations offered for phenomena, which are part of the paradigm, determine the interpretation of the evidence. Explanations which do not fit the paradigm are rejected. Scientists do not "normally aim to invent new theories, and they are often intolerant of those [theories] invented by others" (Kuhn, 1962:24). Indeed if extraordinary, non-confirming results are obtained these may be explained away, for example as artefacts. A theory is seen as correct unless too many
non-confirming phenomena occur when a new paradigm is needed.

Kuhn's view of scientists as traditionalists demonstrating adherence to established theories contrasts with Popper's requirement for refutation. Kuhn implies that the move towards scientific revolutions, large or small, is carried out reluctantly. Not only are established theories not tested routinely but attempts are made to protect and preserve them. For Kuhn, acceptance of novel theories occurs in response to a crisis. He talks of anomalies and counter-instances which are part of all research, part of normal science, yet "every problem that normal science sees as a puzzle can be seen, from another viewpoint, as a counterinstance and thus as a source of crisis" (Kuhn, 1962: 79).

Furthermore even the existence of a crisis does not by itself transform a puzzle into a counterinstance. Instead by proliferating versions of the paradigm, crisis loosens the rules of normal puzzle-solving in ways that ultimately permit a new paradigm to emerge. There are, I think only two alternatives: either no scientific theory ever confronts a counterinstance, or all such theories confront counterinstances at all times. (Kuhn, 1962: 80)

For Popper the importance of falsification necessitates the rejection of an established theory. Kuhn sees that the role attributed to falsification is much like the one assigned to experiences that by evoking crisis, prepare the way for new theory. But he considers that these anomalous experiences may not be identified with falsifying ones, indeed Kuhn doubts the existence of falsifying experiences (Kuhn, 1962).

If Popper presents a picture of a scientist working to engineer or at least identify situations which might refute existing theories, then Kuhn's scientist appears intolerant of discrepancies and challenges to the existing theory. Indeed he or she may see failure to solve a puzzle (in the normal science context) as discrediting the scientist not the theory (Kuhn, 1962). Such may be the situation until the counterinstances and anomalies are such that the situation becomes acute and the rules of normal science become blurred. Fewer and fewer scientists are happy with the existing dominant paradigm. This state is illustrated by Copernicus when he complained about the
inconsistencies in astronomical investigations, and Einstein who wrote that it was as if the "the ground had been pulled from under one, with no firm foundation to be seen anywhere, upon which one could have built". (Kuhn, 1962:83)

Termination of the crisis may occur not by deliberation and interpretation, but by a relatively sudden and unstructured event i.e. when the scientist sees things differently i.e undergoes a 'gestalt switch'. This may be spoken of as "scales falling from the eyes" or a "lightning flash" which shows the discrepancies in a different perspective. From this switch a new paradigm may evolve and new theories emerge, i.e. there is a paradigm shift.

In noting that the tendency is for the paradigm shift to be brought about by young scientists new to the field ("a new phenomenon does not generally win converts, but old scientists die"), Kuhn presents a depressing view of the established scientific community (Donelly in Brown et al, 1986:25). This is food for thought for those engaged in science education as is Kuhn's analysis of the role of science textbooks.

In addition, the manner in which science pedagogy entangles discussion of a theory with remarks on its exemplary applications has helped to reinforce a confirmation-theory drawn predominately from other sources. Given the slightest reason for doing so, the man who reads a science text can easily take the applications to be the evidence for the theory, the reasons why it ought to be believed. Science students accept theories on the authority of teacher and text, not because of evidence. What alternatives have they, or what competence? The applications given in texts are not there as evidence but because learning them is part of learning the paradigm at the base of current practice. (Kuhn, 1962:80)

The layman's and the teacher's knowledge of science is based on textbooks. These are pedagogical vehicles for the perpetuation of normal science and have to be rewritten when the "language, problem-structure, or standards of normal science change" or when there is a paradigm shift.

There is a great degree of agreement between Popper and Kuhn: both deny that
scientific theories are about absolute truth and both acknowledge there is no neutral 'observational language' to which theories may be compared. We see the world in the light of our theories. Kuhn differs however, in his view that "we cannot break out of our theories at any time", and this is, at least partly, "due to the effort with which they are achieved during our scientific education" (Donelly in Brown, 1986:27).

3.12 The Tacit Dimension

For Polanyi verification of any scientific theory involves personal judgement.

Contrary to current opinion, it is not the case that a proven discrepancy between theoretical predictions and observed data suffices in itself to invalidate a theory. (1958:20)

(A premise later developed by Kuhn in Scientific Revolutions)

Science "teaches us how to decide that a particular set of events has occurred accidentally, rather than because certain laws of nature, which these events seem to confirm, are in fact valid" (Polanyi, 1958:33). In demonstrating the role of personal knowledge in interpretation of qualitative, statistical data, Polanyi is attacking the very foundations of physical science. To hold a natural law to be true is to believe it will apply to indeterminate unknown and unimagined situations in the future. "This is to regard the law as a real feature of nature, which as such, exists beyond our control" (Polanyi, 1958:10).

The avowed purpose of the exact sciences is to establish complete intellectual control over experience in terms of precise rules which can be formally set out and empirically tested. Could that ideal be fully achieved, all truth and all error could henceforth be ascribed to an exact theory of the universe, while we who accept this theory would be relieved of any occasion for exercising our personal judgement: we should only have to follow the rules faithfully. (Polanyi, 1958:27)

Laws of classical mechanics closely approach this ideal, he believes, but only if the personal element is overlooked when the formulae of mechanics are applied. Polanyi looks at the passionate quality attached to assertions. "No sincere assertion of fact is essentially unaccompanied by feelings of intellectual satisfaction or of a persuasive
desire and sense of personal responsibility" (Polanyi, 1958:27).

Polanyi argues:

Let me sum up my argument so far. I started with the exact sciences, defining them as a mathematical formalism with a bearing on experience. There appeared to be present a personal participation on the part of the scientists in establishing this bearing on experience. This was least noticeable in classical mechanics and I accordingly accepted that chapter of physics as the closest approximation to a completely detached natural science. Its statements could indeed be so formulated as to admit to strict falsification by experience. There followed two sets of examples for a more massive and not conceivable negligible personal participation in the exact sciences. The first of these comprised the knowledge of probabilities in science; and more particularly of the degrees of coincidence involved in assuming that an apparently significant pattern of events had come about as the result of chance. The second set demonstrated the assessment of orderly patterns in the exact sciences and showed that standards of orderliness, though bearing on experience, cannot be conceivably falsified by it. On the contrary, as in the case of statements of probability, they themselves appraise any relevant samples of experience. (Polanyi, 1958:63-64)

How then can science be distinguished from other areas of human activity if an explicit statement can bear on reality only by virtue of the tacit coefficient associated with it? (The tacit coefficient of a scientific theory is intuition, a discerning, an act of perception, ie ‘knowing’ in Gestalt terms) It (i.e. distinguishing science) becomes possible for Polanyi by reference to relevant intellectual communities. New scientific theories and the scientists proposing them, are judged by the bodies who administer and disseminate science, such as the Royal Society, and by peer review by way of papers presented at conferences and articles in refereed journals.

A pure scientist, who has arrived at an intuitive knowledge of reality, will put his theory before the scientific community and they will judge it by the scientific knowledge they already possess, and only if it fits into this knowledge will the scientific community accept the theory as being confirmed. (Brownhill, 1969:604)
3.13 Objective Science?

The standard view of science is that it is objective and a systematic public enterprise controlled by logic and by empirical fact, whose purpose is to formulate the truth about the natural world:

A fundamental feature of science is its ideal of objectivity, an ideal that subjects all scientific statements to the test of impartial criteria, recognizing no authority of persons in the realm of cognition. (Scheffler, 1967: 1)

The positivist tries to keep science free of any possible subjective input.

The high-risk area for subjective intrusion are theory invention and the smuggling into science of one's favourite metaphysical or religious or philosophical presuppositions. With respect to the latter, positivists claimed that most metaphysics, philosophy and religion were literal nonsense, and they tried to keep them out of science by constructing requirements for confirmation which such principles could not meet. (Ratzsch, 1986: 35)

Since the days of the Vienna Circle at the start of this century, positivism had become discredited as a philosophy of science. Many scientists see themselves as realists.

Men of science, like their non-scientific contemporaries, are liable to have their own pre-conceived ideas as to the way things ought to be in the natural world...we can recognize with hindsight how the breakthrough has come when theorists have had the humility to adjust their ideas to conform to the awkwardness of the way things actually are, whether they liked them or not. (Mackay in Helm 1987: 46)

In stating scientific beliefs, the scientist acknowledges that these may radically change as a consequence of continued testing and scrutiny by the wider community or by her or himself.

Impartiality and detachment are not to be thought of as substantive qualities of
the scientist's personality or the style of his thought... Scientific habits of mind are compatible with passionate advocacy, strong faith, intuitive conjecture and imaginative speculation. What is central is the acknowledgement of general controls to which one's dearest beliefs are ultimately subject. (Scheffler, 1967:254)

Impartiality and objectivity occur not in the "context of discovery" but in the "context of justification", according to Reichenbach (1959). As noted by MacKay above, scientists are not alone in subjecting beliefs to the wider community; philosophers, historians, theologians and others are constantly doing this. Yet although science shares with other areas of life the distinctive features of the rational quest in institutionalising this quest so as to subject an ever wider domain of claims to refined and systematic test, science has given us a new appreciation of reason itself. For Scheffler it is not a matter of free interchange of ideas but of the critical testing of beliefs. Science would seem to differ from other areas of knowledge in that the methodology for the testing is also part of the context of justification. The methodology of testing however involves observation and interpretation. Empirical testing can only succeed where the observers have the same conceptual organisation, when they hold the same theories.

The extent to which one accepts the objectivity of science depends on a number of factors such as how objectivity is defined, which scientific method is accepted and the extent to which one considers the human involvement. For science to be objective, human perspectives have to be excluded. Polanyi rejects objective science arguing that scientists are often deeply and emotionally committed to their work. Assertions, whether scientific or otherwise, have a passionate quality attached to them; they express conviction. The selection and testing of scientific hypotheses are personal acts, but, like other such acts they are subject to rules and the probability scheme may be accepted as a set of rules. Maxims are rules of art. The correct application of maxims is part of the art which they govern (Polanyi, 1958).

As a counter argument it could be suggested that scientific readings are not obtained
from experience but from instruments. Polanyi is not convinced: personal knowledge plays a role even in the collection of data. The empirical testing of scientific beliefs will not ensure objectivity, for knowledge is objective if it relies more on theory than sensory experience (Polanyi, 1958). Humans are cultural beings who are affected by changes in the economic and political structure of society (Polanyi, 1964). This point is reinforced by a feminist thinker:

If science is objective then scientific knowledge produced must be independent of politically motivated interference or direction. Yet how can this claim be maintained when scientists testify before committees and law courts? The structures of scientific production depend on economic and political formation of the society as a whole. (Fee, 1983:20)

Science cannot be separated from the subjective and personal even though the majority of scientists still think within the constraints of the mechanical model (Birch, 1990). The objective, positivistic mechanistic view is challenged by the new physics, some areas of the new biology and creative non-traditional thinking in theology and philosophy. For Polanyi science came to be reduced in the modern mind to the rank of a convenient contrivance, a device for recording events and computing their future course.

3.14 The Social Construction of Science

Passmore warns that "antiscience sceptics seek to overthrow the concept of objectivity" (1978:81). Gergen and Gergen acknowledge the problem of completely rejecting objectivism and indicate a means of reconciliation:

"Are we to dismantle the scientific apparatus, declaring all attempts at being 'objective', 'authoritative' knowledge to be fatuous? Are we to conclude that because we are each locked into our subjectives we cannot even be certain that there is a 'world out there', or that we are truly communicating with other persons? ... These are all dolorous conclusions, indeed, and one would scarcely wish to pursue lines of thought for which these are the inevitable consequences. However, the consequences of obliterating the subject-object dichotomy largely depends on how we understand or interpret the problem. It is our view that if
a social constructionist view is taken toward the issues, none of the above conclusions need to follow. (Gergen and Gergen in Steier, 1991:77)

Social constructionism concentrates not so much on the descriptive language of science, concerned with mapping and picturing the world, but on language in transmission and communication, language which is "essential in coordinating the activities of scientific communities around mutually agreed upon problems (for example, of prediction and control) " (Gergen and Gergen in Steier, 1991:78).

The emphasis is not on the origin of ideas within the heads of individuals but on mutual understanding of ideas using language, language which is culturally determined. Scientists have "a range of linguistic predispositions already at hand and to generate understanding they apply the existing language".

The scientific investigator must bring to bear language forms acceptable by current standards of intelligibility within the profession... The confirmations (or disconfirmations) of hypotheses through research findings are achieved through social consensus, not through observation of the 'facts'. The 'empirical test' is possible because the conventions of linguistic indexing are so fully shared ('so commonsensical') that they appear to 'reflect' reality. (Gergen and Gergen in Steier, 1991:80-82)

Scientists arguing that research findings are modified by empirical research, are misguided according to social constructionists. It is not more empirical research which is required but questioning of the theoretical assumptions which underpin the research. Scientific knowledge is not to be found ready-made but is a human construction which involves continual reflection by individuals and communities.

reflexive consideration of various forms of discourse should be a continuous undertaking in which all subcultural enclaves should be invested. (Feyerabend, 1981:17)

3.15 Summary

Although there are common aspects in all the above analyses, namely
the formulation of hypotheses;
investigative processes;
collecting data and evidence;
analysing and interpreting data;
the formulation of theories,

there are variations in how the nature and remit of science are perceived. How valid or idiosyncratic a new theory is perceived to be, depends on the methodology used by research scientists along with the opinions of their peers. This peer analysis leads to local or universal acceptance or rejection of an individual's theory. An essential part of this acceptance process is that the investigations carried out and the data collected to substantiate hypotheses and which leads to formulation of theory, must be reproducible. This is essential, for data from investigative processes is the evidence for the theory. A theory should also be applicable to contexts other than the one in which the theory has been generated.

Inductivism implies that reality can be comprehended using our senses yet, in furthering this understanding, the scientist delves deeper and deeper using theoretical concepts, and today he or she no longer relies on the senses alone. Much of present day 'pure' science research is concerned with particle physics and cosmology and by its very nature this is not dealing with reality which can be experienced. It is based mainly on theoretical, mathematical reasoning.

Theoretical physicists are using processes which do not conform to scientific methodology to make statements about certainties or near certainties. (Oldershaw, 1990: 56)

A Kantian view of pure science - that it can only be concerned with understanding what can be seen - is no longer appropriate. Acknowledging the role of speculation, of theory, of falsification, leads me to favour the hypothetico-deductivist approach as outlined by Medawar. (see section 3.9) In saying this I recognise and value the personal elements and the tacit dimension in the science process and, along with Polanyi, Kuhn and Lakatos, reject the positivistic approach. I particularly appreciate Kuhn's description
of science as a body of belief (see section 3.11). This implies that different perceptions and interpretations of science are possible and acknowledges the personal and the tacit. It thus becomes possible to embrace women’s interpretive frameworks as described by Gilligan.

The use of the term ‘objective’, while probably inevitable, is likely to be a source of confusion and controversy. For me objectivity can be used to describe science, only if this is seen in Scheffler’s terms i.e. the critical testing of beliefs by placing them into a wider arena for discussion when people are given the opportunity to participate in decision-making (see section 3.13). I acknowledge however, that the opportunity and ability to believe in absolutes, in facts and truth produced by experts becomes more problematic when more people are involved in the decision-making. If one is participating in constructing the knowledge it becomes more difficult to believe in certainties and to place one’s trust and faith in such knowledge. Engaging in critical analysis means learning to live with uncertainties (Hull, 1985). This may be one reason why, as Chalmers noted (see section 3.4), the inductivist view of science is popular.

The interpretation of objectivity as the ‘putting into a wide arena for discussion and critical evaluation’ not only enables more people to be involved in decision-making, it is a useful model for developing awareness of valuing and the importance of value-judgements. It also coincides with a view of education which is about developing the individual’s ability to think critically. This leads me to examine the aims for education and in particular for technology education.
Dear Teacher
I am the survivor of a concentration camp.
My eyes saw what no man should witness:
Gas chambers built by learned engineers.
Children poisoned by educated physicians.
Infants killed by trained nurses.
Women and babies shot and burned by high school and college graduates
So I am suspicious of education.
My request is:
Help your students become human. Your efforts must never produce
learned monsters, skilled psychopaths, educated Eichmanns.
Reading, writing, arithmetic are important only if they serve to make our
children more human.
(quoted in Pitt, 1991:34)

4.0 Valuing and Education

People may argue that education is, and should be, value-free and should avoid learning
approaches which touch upon attitudes and feelings (Scruton, cited in Wellington,
1986). However many educators cannot conceive of value-free education or of a value-
free curriculum.

...teachers cannot avoid imparting values in one way or another in the normal
course of their activities...value judgments play a critical role in decisions
affecting the curriculum, extra-curricular activities, schools regulations, and
school-community relations. Indeed, value judgments may be said to permeate
the very fabric of the educational process because they influence practice in ways
ranging from the basic learning climate of the classroom...to the everyday tasks
of grading essays, selecting textbooks, and planning teaching units. (cited in
Carbone, 1991:290)

As Purpel and Ryan noted in 1976 (cited in Carbone, 1991) values go with the territory
i.e. with education. Any institution is concerned with and holds to, certain values.
Whether these are acknowledged or questioned is, however, another matter.
Questions about values are crucially relevant to many current issues in education, for example the "child-centred" approach compared with the "subject-based" approach. Values are also inherent in the rationale for education. Watson (in Montefiore 1992:129-131) identifies five approaches:

1. The liberal concept of education;
2. The utilitarian model;
3. The so-called academic approach;
4. The ideological approach;
5. The moral and cultural approach.

Each approach will be justified using different value positions but which in reality have considerable overlap.

A.V. Kelly talks of two main pressures on education:

...those indirect influences which are generated by the organizational contexts within which we work and by all the many groups in society which seek to steer the work of schools into certain directions in which they have some vested interest, and the more direct or, since the 1988 Education Act, the very direct impact of political initiatives taken by central government. (A.V. Kelly, 1989:21)

Acknowledging that it is an over-simplification, Kelly notes that educational objectives are sometimes defined as vocational or utilitarian being concerned with training people for work roles. He sees central government intervention as a move to limit, indeed remove, teacher influence on the school curriculum in order to make the education system more economically productive.

In contrast, educational objectives may also be concerned with developing autonomy and personal development. (Pring cited in Downey & Kelly, 1975:137) A.V. Kelly (1989) believes that most teachers see their role in furthering personal development, and that this is a major reason why central government control has been imposed.

4.1 Knowledge and Values

There is a tendency to discuss [educational] issues at the level of shared
assumptions about knowledge and values, without ever establishing whether those assumptions are shared or not - either because such assumptions are accepted uncritically or because their problematic nature is not recognized or understood. (A.V. Kelly, 1986:5)

Much has been written about knowledge in the curriculum. Kelly identifies two broad perspectives, the rationalist perspective and the empiricist perspective. The rationalist view emphasises reason and sees the rational mind as a source of valid knowledge. This view accepts that some knowledge is certain, regards it as in some sense having a status, and indeed an origin, quite independent of individual human beings and believes that this status extends also to the realm of values…its proponents speak of ‘moral knowledge’, for example, and regard that as having a status quite independent of individual beliefs and preferences and thus a high degree of certainty. (A.V. Kelly, 1986:71)

This view opens up a metaphysical perspective which transcends experience and perception. It accepts the validity of knowledge as a priori, independent of any experience of the senses. A strong view of truth is presented and large areas of knowledge are seen as certain. Knowledge is propositional i.e. ‘knowledge that’, and justification can be found for assertions of value - moral, aesthetic and educational in reason itself; in the concept of the rational mind.

An empiricist view sees knowledge as uncertain and hypothetical. Knowledge is procedural as ‘knowledge how’, a means of coming to learn, to understand and to think. It believes that no ultimate justification of an objective kind can be found for any assertions of value, that values are relative, man-made, ‘socially constructed’. (A.V. Kelly, 1986:6)

If empirical knowledge is completely individual, personal and idiosyncratic and perceptions are completely private and cannot be communicated to others, then such a view would make educational planning impossible to achieve. However:
in the realm of values, this perspective is crucial to educational planning... It is perfectly possible and quite reasonable to accept that there is a body or there are bodies of knowledge of a 'factual' kind in many areas of human experience and that these bodies can be built on, added to and communicated to others, while not accepting that here are comparable bodies of moral knowledge or aesthetic knowledge or social/political knowledge. (A.V. Kelly, 1986:71)

Sociologists who consider knowledge to be socially constructed, warn of the danger of accepting the rationalist view that certain bodies of knowledge have a right to be part of the curriculum, for such acceptance entails accepting also the values implicit in those bodies of knowledge (Dewey, 1916; Young, 1971).

Values are not entities having some kind of existence of their own... valuing is an activity... and different people do it differently. (A.V. Kelly, 1986:42)

Activities do not have intrinsic value, it is humans who place value on them. A view of values as deriving validity from actual choices made by people is concurrent with a view of people as active rather than passive beings. A model of active learning implies that the individual has a right to do his or own valuing. Kelly considers such a model a way of distinguishing education from training or conditioning (A.V. Kelly, 1986:43).

4.2 Values Education
Wellington (1986) notes that controversial issues are inherent in issues involving human activity and that these are matters of value and not facts. Along with Dearden (1984), A.V. Kelly, (1986, 1989) and Midgley (1992), he also notes that facts cannot be separated from values and that factual knowledge is also controversial. To be worthy of inclusion in the curriculum, issues must involve value judgements.

In teaching about controversial or value issues there are three considerations for teachers - objectivity, balance and neutrality and all are linked to the role of the teacher as an authority. Wellington says the key question in handling controversial issues is "To what extent should teachers act as an authority in the classroom?"

A teacher may well be able to adopt the role of a factual authority... Thus, in
discussing nuclear energy, a science teacher could usefully correct the mistaken belief that a nuclear reactor could (in the event of an accident) explode like an atomic bomb. But should he or she act as ‘an authority’ in settling matters of value? Clearly, a teacher who did so would not be acting objectively, neutrally, or in a balanced way. (1986:4)

Objectivity is said to be difficult if not impossible, and Wellington wonders whether teachers should attempt to confine themselves solely to matters of fact and avoid, or stop short of, questions of value. He considers this is not possible for some facts are value laden and values are dependent on people’s perceptions of the facts (Wellington, 1986:4). In teaching about some areas such as nuclear power, Wellington while noting what Stenhouse (1975) says, namely that instruction inevitably implies that the teacher cannot maintain a neutral position, believes the provision of information, and even direct instruction, is central to an understanding of the nuclear issue. Information is needed to enable pupils to make informed value judgements rather than gut feeling or intuition.

4.3 Deconstructing Knowledge
A teacher trainer concerned with the empowerment of teachers and learners, defines deconstruction as:

a sense of one’s power to interact creatively with others and with the natural world: clarifying our concept of what it is to be human. (Bearlin 1987:3)

Bearlin believes teachers should be helped to examine any content to be taught and teaching matter for underlying or explicit ideologies. She notes that determinist theories have been used to support sexist, racist and classist ideologies. She advocates the use of teaching and learning strategies, the basis of which is the need to deconstruct and reconstruct knowledge and practice in relation to one’s own value system or world view. She cites as an example demystifying theories of biological determinism. An active view of learning is promulgated which deplores the passive acceptance of knowledge and the ability to be manipulated by experts.
Teachers must be able to DECONSTRUCT, or critically examine for underpinning assumptions, all theoretical knowledge and educational practice, both what and how they will teach. For example: Where did this knowledge come from? What was the purpose of the research? How was it funded? In whose interests does such knowledge operate? What views of humans / nature / society / knowledge are implicit? Are people seen in terms of gender, class ethnicity? Who / what is left out, or differentially treated? How do I know what is claimed to be true is true? What evidence /argument supports it? Are limitations explicit in the conclusions etc etc. Teachers must also be able to RECONSTRUCT knowledge, so that both they and their students are empowered rather than depowered by it. This knowledge, or naming, then must be continuous with their experience, embodying their values, enabling them to see the world in a way that makes their own understanding of it; and action in it, possible and worthwhile, indeed possible because it is seen as worthwhile. "(Bearlin, 1987:5)

This deconstruction and reconstruction means learners need to be made aware of different belief and value systems but not at the expense of seeming to suggest equality of worth where it does not exist, or that all things are personally subjective. (Williams, 1990b:6)

4.4 Values and Religious Education, and Personal and Social Education
Religious Education (RE) is concerned with values education (Mellor, 1990). Plunkett (1989) considering the implications of the Education Reform Act of 1988, asks how the Act might be the "basis for some new energy in values teaching". He suggests RE teachers will be obliged to seek help from colleagues and also asks whether teachers "will be encouraged to adopt broad definitions of ‘Christian character’ that will be acceptable to multi-faith and agnostic communities" (1989:28). In today’s multicultural, pluralistic society the notion of universal values is challenged.

Pluralism of culture, belief or approach does not necessarily mean plurality of concepts of value against which ideas, feelings and actions are evaluated, although it may mean differences in outcome. Pluralism may mean that
problems exist where there is both a need to give respect to traditional beliefs and values and to individual freedom of choice, responsibility and autonomy. Such conflicts can only be resolved when an agreed basis for beliefs and values is drawn up on a way which is non-indoctrinatory…RE is central to the teaching and learning of beliefs and values because religious beliefs underlie many of the values positions which people hold to, without fully understanding their reasons for doing so. The role of religious education is to create opportunity for a conscious exploration and understanding of these hidden assumptions. (Williams, 1990b:5)

In addition religious education offers a range of strategies and processes which encourage a reflective approach to values and belief. Thinking specifically of adult religious education (ARE), James (1989) believes it attempts to foster critical consciousness and that ARE should include the relentless testing of the newest possibilities against the oldest in values, a process which happens particularly in adolescence. (Erikson, 1982: 93)

The RE Values Project identified RE’s unique role in values clarification for it is concerned with:

- a dimension of life
- traditional customs/culture
- reflection
- symbols
- spiritual dimension
- thinking about ethics
- liturgy
- answering ‘why’ questions
- community
- awe and wonder (Williams, 1990a)

Another area involved in developing values awareness is Personal and Social Education (PSE) (Pring, 1984:6). PSE is concerned with process rather than content and focusses on experiential, active learning styles; content is selected only for its relevance to life.
4.5 Strategies for including Value Issues.

Controversy exists because people start from different belief systems and assumptions. Purpel argues that the technical, instrumental rationality "so celebrated just a short time ago has proven inadequate to deal with the massive social and cultural crises" of our era and the chief movements in recent education such as values clarification, and the cognitive development approach illustrate this. (cited in Carbone, 1991: 291)

The ROVE project (Research on Values Education) recommends a personal, reflective approach and in particular the use of narrative in dialogue, journals and diaries often used with trigger cards and films. (Francis: 1992)

Another approach takes a form of laddering, reminiscent of Personal Construct techniques and analogous to peeling an onion (Cross, 1987). Williams devised a value mapping process for schools which starts with a problem or issue:

- Problem (involving conflicting values or conflicting needs or problems)
- Issues (identify)
- Values (examined & clarified)
- Beliefs and Hidden Assumptions (revealed)
- Listing priorities
- Reducing/ resolving conflict- balancing priorities, thinking ahead, predicting outcomes, group rather than one view, past experience-review, considering several solutions.
  (Williams, 1990a)

Watson (1990) addresses the "problem of an individual standing out for their values", within a relativistic paradigm and suggests ideas for breaking relativistic deadlock based on 'Criteria for Discernment'. An individual taking a stance on values must address such criteria as:

- Is there competent authority?
- Can the values be explained? Are the values comprehensive?
- Do the values have a common sense basis?
- Is there a logical coherence?
Is there clarity about the values?  
Are the values consistent with lifestyle?  
Is there an accurate/empirical ‘fit’?  
How vigorously are the values held?  
What are the consequences of holding the values? (Watson, 1990)

Another approach in a Postgraduate Certificate in Education course, used the following questions:

What values do we bring with us from our disciplines?  
What values come from Western cultures or society?  
What values did you find in schools?  
Did they conflict with your values about teaching?  
What do you do now then? (Selmes, 1991)

People often find it difficult to express their own value positions lucidly and concisely.  
Jenkins (1991) suggests that using approximate equivalents like principles, beliefs, guide-lines or even ethics may help.

For these ideas and processes to be used they must have content and relate to a context; technological topics can provide this.

4.6 Taking an Issue-centred Approach

In the GATE (Girls and Technology Education) project 1982, Grant argued that a start can be made within the area of any one of the three inter-locking components of Design and Technology capability: skills, knowledge and values.  
Most approaches to technology teaching have an initial emphasis on either problem-solving skills [e.g.] design a model boat to travel a 4m length of guttering or the application of knowledge [e.g.] using knowledge gained from an investigation into the interrelationships of light and colour,[ when] making a 3D Animal Head Mask’). In both approaches, the values component is likely to receive scant attention. In its absence technology can too easily be seen as largely concerned with technical solutions to technical problems...and its relevance to people, quality of life, social problems and values become submerged and invisible. (cited in Conway and Riggs, 1992:30)
The starting point might be a social issue (Harding and Grant, 1984; Pitt, 1991) thus changing the emphasis from the impersonal to the human and from the exclusively technical to sociotechnological. In this approach the values component is highlighted and is used to initiate and guide the designing and making activities. Specific problems connected with the issue are identified by pupils and the appropriateness of social, economic, and political proposals are given the same critical consideration as are all potential technical solutions.

The Development Education Centre (DEC) in Birmingham produced a book entitled Why on Earth?: an approach to science with a global dimension at key stage 2. This takes an issue-centred approach.

There is evidence to show that children learn most effectively and enthusiastically when their learning is firmly set in a real context. They find a real purpose for investigating, discussing and exploring (DEC, 1991: 8).

In the aims for such an issue-centred approach, the DEC hopes that pupils will gain some understanding that people hold different points of view and will enable pupils to explore why this is so. In doing this it is hoped pupils will identify their own attitudes and what influences them. The need for such recognition applies also to teachers.

The Humanities Curriculum Project gave guidelines for teaching about 'the nuclear issue':

1. Teachers should not use their authority as teachers as a platform for promoting their own views.

2. The mode of enquiry in controversial areas should have discussion rather than instruction in its core.

3. Discussion should protect divergence of view among participants.

4. The teacher as chairperson of a discussion should have responsibility for quality and standards in learning. (cited in Wellington, 1986)

The importance of discussion is recognised in the Discussion in Science and Society (DISS) project although the format of discussion is different from the above for the students are given control.
4.7 The DISS Project
The Discussion in Science and Society (DISS) project is part of a linked research programme on the Public Understanding of Science which is looking beyond the normal meaning of 'understanding'. The different projects are exploring how much emotive reactions as trust or distrust, fear or wishfulness, and even the glamour or status of the knower, affects how scientific knowledge is received...the group 'reconstructs' the scientific knowledge in order to see its relevance to them. (Solomon, 1991:33)

The students took responsibility for the nature of the discussion and for the means of recording the discussions, i.e. the teacher did not act as chairperson of a discussion. Taking responsibility enabled students to develop social solidarity which led not to finding right answers but to the setting of the issue in a more familiar context.

By careful deliberations and through helping each other to imagine the possible consequences, their scientific knowledge from school and the video was gradually put into a personal perspective. Other connections between discussion of social issues and scientific knowledge appeared. One was the frequent comment that 'we need more research' which usually signalled their arrival at a point where no one in the group had relevant information...when the group felt they were being fed with biased or incomplete information, or when they felt powerless in the matter they could be made angry or disaffected...The incentive for discussing social issues constructively is not successful assessment, nor just relevance, it is the feeling that the citizen can achieve some just social objective through the combination of scientific understanding and social evaluation. (Solomon, 1991:33)

4.8 Teaching about Values in Science and Technology
Bridges (cited in Wellington, 1986) believed most of the science and technology in schools is taught as if it is non-controversial even though few teachers would deny that there is considerable controversy about science itself, i.e. not only about the applications of science. It seems that many science teachers continue to facilitate students' learning of attitudes and values through the hidden curriculum (McBrien and Martin, 1994).
Because values are not explicitly discussed in science does not mean that values are not being transmitted and learnt (Layton in Tomlinson and Quinton, 1986). Put another way, teachers who teach science as if it is value-free are guilty of "indoctrination by omission" (Black, 1990). Williams, like Bearlin (see section 4.3) suggests that to avoid such indoctrination assumptions should be revealed at the outset and the teacher should consciously examine content for balance, and teaching and learning methods for openness. (Williams, 1990b:6)

This is particularly clear in multi-cultural education which has raised issues of institutional and unintentional racism. The science curriculum is biased towards a European / North American viewpoint. The oft stated phrase "I am not a racist, all children are the same to me", is a good example of unintentional racism. This sentiment completely ignores the multiplicity of values, backgrounds and experiences of pupils. Not to recognise this diversity is to deny the value of their inheritage. This in turn leads to negative feelings towards peoples from certain ethnic groups. (ILEA, cited in Arora & Watts, 1986)

This ignorance of the contributions of other cultures is not surprising given the history of colonialism. McAuley's minute in the Charter Act of 1813 well indicates the denigration of South Asian culture.

A single shelf of a good European history was worth the whole native literature of India and Arabia...We must at present do our best to form a class who may be interpreters between us and the millions who we govern; a class of persons, Indian in blood and colour, but English in taste, in opinions, in morals, and in intellect. To that class we may leave it to refine the vernacular dialects of the country, to enrich those dialects with terms of science borrowed from the Western nomenclature, and to render them by degrees for vehicles for conveying knowledge to the great mass of the population. (Goonatilake, 1984:95)

This is an example of an imposed curriculum rather than a hidden curriculum.
Science and technology teachers cannot ignore outside influences upon the attitude, motivation and self-image of pupils. Examination of much curricular material shows that rarely are representatives of ethnic minorities shown or perceived to be in positions of power or authority in science and technology.

4.9 Curriculum Materials
Curricular material exists for discussing the social implications of science and technology e.g. SATIS (Science and Technology in Society). Much of this material raises awareness of the issues and often presents a number of perspectives on an issue thus encouraging students to 'weigh up' the matter and come to some decision. Although students are encouraged to make value judgements, these materials do not usually ask students to examine the values they are bringing to bear when making decisions. Readers are also not encouraged to consider the belief, perspective or framework in which they operate.

In a booklet, Exploring the Nature of Science, Solomon includes a section in the introduction termed 'Teaching Moral Values' in which she notes that:

Some teachers felt intimidated by the idea of 'teaching morals': probably because it seems unfamiliar to them. However both as parents and as form-tutors most have already been called upon to guide children, so there is really no need for this diffidence. Other teachers have argued that ethical issues should be dealt with in religious, or personal and social education, because coping with moral questions is a task requiring special skills. (Solomon, 1992)

It is said that two units in the booklet may be used to raise ethical values but the words are not used in the relevant section and pupils are not asked to justify decisions. In another book Race Equality and Science Teaching (Thorpe, 1991), values and/or beliefs are not addressed although pupils are encouraged to challenge assumptions especially in the sections entitled "Ideas about science" and "Images in Science" (Thorpe, 1991: 24, 52).

Books on religion and science and technology encourage students to question the nature

4.10 Summary

Values and beliefs are emotive issues. Watson (1990) believes this is one of the reasons why values and beliefs are ignored. Another reason she suggests is the question of relativism. Both are unacceptable for she considers beliefs are particularly important because they are sources of motivation and a person’s or group’s convictions are a consequence of their beliefs and such convictions give vision. This linking of beliefs with a vision is valuable for I believe we need a vision for technology education which can be justified with recourse to explicitly stated educational beliefs. It is possible however, to avoid any discussion of beliefs and values and this seems to be the case in much of the science and technology material currently available. Such material raises the issues and encourages discussion of different views, perceptions and possibilities but there is no attempt to make explicit the values and beliefs behind the issues. Discussion frequently remains at the level of ‘I think this’, ‘You think that’; prioritising is ignored and there is no requirement to justify thoughts and decisions.

Education cannot be value-free. Indeed Peters (1966) defines education as passing on what is worthwhile; thus values, determining what is worth, lie at the heart of education. This research is concerned with what is or should be passed on in technology education.
CHAPTER 5   THE RESEARCH QUESTIONS

The growing conviction that 'controversial' issues should be part of biotechnology teaching (see Introduction) led me, through reading and discussion, to the realisation that I needed to concentrate on how decisions are made. I was clear that decision making involves value judgements and that the values people hold and bring to bear in decision-making originate from their beliefs (beliefs are also described as constructs or frameworks of meaning - see section 1.3; 1.9; 1.11). I understood that in making a decision a person judges or chooses what should happen with reference to what he or she, or a relevant group, believes to be important.

Beliefs are sometimes interpreted as attitudes, for attitudes, like beliefs, can be interpreted as mental constructs but attitudes are usually indicative of people's feelings and behaviour. I rejected investigation of attitudes, justifying this by noting that feelings and behaviour are consequences of beliefs but the concept of belief is wider for it suggests an external, shared dimension, - external, that is, in terms of shared reality or intersubjective constructs. The thesis would be concerned with individual and group beliefs of science and technology educators and hence the external, shared dimension would be important.

The beliefs people hold, of which they may or may be not be aware, are various. Gaining insights into people's values and beliefs can be problematic (Watson, 1990) and it cannot be assumed that members of a group share the same beliefs. Although aware of this and the related problem of generalising, I considered that Gilligan's (1982) work, which indicates that women tend to value human relationships more than do men, to be very important. People hold beliefs about numerous things. The research needed to be restricted to particular areas of belief.

My reading about technology, briefly outlined in Chapter 2, pointed to confused perceptions of the nature of technology and to links between science and technology. This link is particularly evident in the biotechnologies (Smith,J., 1988; Hayward,
1990). From the literature I also noted the arguments for the value-laden nature of technology (see section 2.4) and for the prevalence of a technicist belief is prevalent in modern society (see section 2.5).

Recalling Pacey's discussion of world views and the relating of scientific theories to decision making (1992), Winner's (1986) concepts of technical determinism and scientific certainties, Franklin's (1990) prescriptive technologies, and Lally's statement that technicism is based on scientific reasoning (see section 2.5) I realised I would need to probe the connections between science and technology. I thought that a technicist view was inconsistent with acknowledging the value-laden nature of technology. I would thus probe perceptions about the nature and remit of technology with particular reference to valuing.

In Chapter 3 I have outlined my understanding of science, gained from the literature. I arrived at an image of science as a continuum, one pole of which could be defined as 'hard' science - impersonal, mechanistic, deterministic and concerned with proven facts. At the other pole was science as socially constructed knowledge which arises from shared perceptions and explanations (Berger and Luckmann, 1967). It seemed to me that the view of science as proven facts had echoes in the determinist, technicist view of technological developments.

As a science teacher I had never questioned my beliefs about the nature of science. As I read the literature and wondered about the image of science I had presented to my students, a hypothesis emerged. This was that the beliefs or constructs educators have of science and technology influence how they teach and whether they include or exclude values. From this I identified three areas for investigation:

1. What are science and technology educators' beliefs and perceptions about science and technology?

2. Is valuing and awareness of value judgements in decision-making included in science and technology education?
3. How do educators' beliefs and perceptions about science and technology influence whether they include awareness of values in their teaching?

I decided to start by investigating the beliefs people hold about science. This included probing the nature of science, understandings of facts (it is suggested that facts are sometimes contrasted with values) and ideas about scientific objectivity. In section 3.15 I have declared my view of objectivity as a critical testing of ideas and beliefs when these are placed in a wide arena. I thought it important to know whether educators define objectivity in a similar way or whether they see objectivity in terms of immutable, impersonal truths or facts. In order to do this I intended to assess whether people thought that science is concerned with a search for knowledge for its own sake or whether it is a means to an end, i.e. has a utilitarian basis. I also intended to probe understandings of the role of scientists. To effect this I would use questions such as:

Should science be carried out because there are potential benefits for society?
Should scientists be concerned with the potential effects of their discoveries?
Is science seen to be concerned with finding the truth?

Watson (1990) speaks of the role of values and beliefs in the owning of a vision; I was interested in the vision for technology education. Translated into a research question, this related to the aims for technology education. One way I thought I could find out about this was to ask if students were encouraged to discuss how decisions are made in their own technological activities and in technological activities carried out in society. The idea was also to assess whether educators thought students should be helped to see how social and values issues impinge on technological developments, and where and how in the curriculum this should be done. Technology is value-laden, as is all education. The inclusion of values should be unavoidable in technology education. Acknowledging this, part of the research would ask about the influence the inclusion of values has on students' perceptions of science and technology and their future careers, e.g. Are children encouraged or discouraged to follow scientific or technological careers and careers in industry when values are included?

I had thus identified the field to be researched. The next concern was to survey possible
ways to carry out the research. Having realised that values and beliefs are emotive issues which cannot be understood in terms of rational intellectual thought alone, I knew that the research approach and techniques would have to be carefully chosen.
CHAPTER 6  METHODOLOGY

6.0 Introduction

Literature is available for teachers wishing to include social issues in science and technology lessons, but there appears to be little empirical research regarding discussion of value judgements in such lessons. There is also minimal literature about how teachers’ beliefs influence the inclusion of value issues in science and technology teaching. Carrying out research into people’s beliefs and attitudes is quite difficult. In attempting to do this the benefits and limitations of various research methods will be evaluated.

6.1 A Philosophical Overview.

Natural science methodologies are typified by activities such as hypothesizing, experimenting, observing and postulating theories. An experimental approach will not be appropriate for this research. First there is no hypothesis to be tested. Second, carrying out observation at a distance from the subjects, i.e. the educators, is unlikely to provide information about people’s beliefs. Observation might provide data on the behaviour of teachers and students and while accepting that values, norms and beliefs may be significant determinants and explanations of a person’s behaviour, it cannot be assumed that the way a person behaves correlates with the beliefs he or she holds.

The application of natural science methodology to social phenomena is often described in terms of positivism. Comte, one of the founding fathers of sociology believed the aim was to understand and explain human interaction and behaviour using the methods and principles of the natural sciences, for these methodologies had apparently proved to be very successful. The application of conventional methodology to the social sciences has been widely criticised. Such criticism centres around two points:

First [the methodology] fails to take account of man’s unique ability to interpret his experiences and represent them to himself... Social science, unlike natural science, 'stands in a subject-subject relation to its "field of study", not a subject
-object relation; it deals with a pre-interpreted world in which the meanings developed by active subjects actually enter into the actual constitution or production of that world. Second, the findings of positivistic social science are often said to be so banal and trivial that they are of little consequence to those for whom they are intended - teachers, social workers. (Cohen and Manion 1989:22)

One might add that natural science methodology not only fails to take into account people's values and beliefs, it does not allow for human beings' ability to reflect and change their values and beliefs in the light of experience.

6.2 Qualitative Methodology

Within the social sciences, qualitative methodologies assume that to achieve understanding of people, the researcher has to involve herself in the life of the people being studied. Interaction between researcher and researched is promoted rather than observation from a distance. The researchers attempt to put themselves into the position of the observed and so try to understand the "underlying assumptions of behaviour (Rist, 1977:45). The researcher begins

   not with models, hypotheses, or theorems, but rather with the understandings of frequently minute episodes or interactions that are examined for broader patterns and processes (Rist, 1977:46)

Byrne (1990) believes that the qualitative researcher does actually start with a hypothesis and must stop at every stage of the research and re-examine his or her hypothesis. The hypothesis constantly changes, as for example in grounded theory. This is different from the natural science approach where attempts are made to substantiate an initial hypothesis by controlling variables.

   It should not be assumed that qualitative methods are insightful, and quantitative ones merely mechanical methods for checking hypotheses. The relationship is a circular one; each provides new insights on which the other can feed. (Pool cited in Lindzey and Aronson, 1968:600)
Such a relationship is descriptive of this thesis. The use of questionnaires with controlled variables and a pre-determined scale is quantitative. However the prime reason for using questionnaires was not to look for general laws or patterns but to identify areas which could be probed at interview, a qualitative research tool.

6.3 Professional Competence

The research questions previously identified are within, what Carr and Kemmis call, the philosophical view of the professional competence of teachers

[that is] the need for teachers to accept a reflective stance towards the fundamental assumptions and ideals on which their 'philosophy of education' depends. The purpose of [this] research, therefore, is to provide teachers with the type of concepts and insights that are required to formulate a coherent understanding of the nature and purpose of the educationer's role... Professional competence is, therefore, a matter of making judgements in accordance with fully articulated principles, values and ideals. (quoted in Pope and Gilbert, 1986:10)

The professional may articulate the principles, values, beliefs and ideals which he or she holds or may be repeating those held by others.

6.4 An Interpretive Framework

Phenomenological and interactionist approaches are described as:

interpretive, for both stress that belief that the 'external' world can only be known to us through the operation of our minds, and that our minds are not blank, but furnished with mental structures which affect our perception and understanding of that world. (Worsley, 1978:61)

An interpretive approach is

not concerned so much with explaining behaviour as understanding actions...and...is concerned with individual perspectives, personal constructs and negotiated meanings. (Cohen and Manion, 1989:25)
The interpretive approach "has been used as an inclusive term for the various approaches used in ethnographic research." (Goodson and Walker in Sherman and Webb, 1988:114)

A naturalistic researcher is a phenomenologist concerned with describing and understanding social phenomena who:

- begins as an anthropologist might begin by...immersing himself in the investigation with as open a mind as possible, and permitting impressions to emerge. Anthropology is concerned with culture as manifested in people’s verbal and non-verbal behaviour. Ethnography is the science of cultural description and thus is concerned with describing behaviour, beliefs, attitudes and values of the people under study. (Shimahara in Sherman and Webb, 1988:78)

Illuminative research is concerned with description and interpretation rather than measurement and prediction (Parlett, 1981). An interpretive approach seemed suitable, however the inherent problems and limitations were noted. The following quote discusses the some of the problems of the illuminative approach.

- The very sensitivity and flexibility which are the essence of illuminative research are also its Achilles’ heel. The insights which emerge from qualitative research reports can appear too much the product of the researcher’s personal perspective and of the idiosyncracies of the specific situations examined. If the psychometric analyses impel the research towards oversimple generalisations, the illuminative method can also mislead by swamping the researcher in particularities of doubtful general validity. But good qualitative research can through cross-checking of interpretations and through awareness of its limitations, provide evidence as strong in its own way as that derived from conventional approaches. (Entwistle and Hounsell,1970:361)

6.5 Taking a Naturalistic Approach

Guba (1978) describes the natural science, experimental approach as ‘conventional’ and contrasts this with a naturalistic approach. Heron talks of conventional and
autonomous cultures. A person may act autonomously i.e. as a consequence of their beliefs which have been thought through before he or she espouses them, or the individual may act within a conventional framework i.e. act on, and espouse beliefs because the beliefs are held by others but these have not been thought through by the individual. Whether the individual holds their beliefs autonomously or conventionally, Heron notes that the researcher needs to participate in the cultures through dialogue and interaction (in Reason and Rowan, 1981).

Having identified the basic research questions the decision was taken to work within a naturalistic paradigm. The next step was to consider the basic approach and research techniques which might be used.

Noting above that the interpretive approach 'has been used as an inclusive term for the various approaches used in ethnographic research', ethnographic techniques were considered.

Ethno-graphy means literally description from the natives' [the people being studied] point of view: rather than imposing one's own framework upon the situation, the ethnographer tries to develop an appreciation of the way natives see things. (Woolgar, 1988: 84)

Hence an ethnographic enquiry:

aims to bring to life by close observation and/or depth interview the internal workings of an institution or culture, to reveal the perspectives of members, to highlight the constraints they work under, the kinds of adaptations they make as a result, and to make explicit the routine and taken-for-granted features of institutional life on which orderly management may depend. (Hargreaves and Woods, 1984: 6)

The researcher working in an ethnographic paradigm formulates guiding questions, which may be regarded as tentative hypotheses, after the orienting phase of fieldwork, but he or she does not formulate questions or hypotheses prior to starting field work.
Ethnography is a process and a model for this process might be:

- **Learn something**: Collect some data
- **Try to make sense of it**: Analyse
- **Check interpretation in light of new experience**: Collect more data
- **Refine interpretation and so on…**: Carry out more analysis

(Smith, 1990)

The procedure above provided a framework for the field work. Shimahara notes that ethnography has no standardised procedures of investigation that all ethnographers use. Indeed ethnographers often combine different methodological techniques, some of which are devised personally, in such a way as to facilitate data collection in particular field situations. (Shimahara in Sherman & Webb, 1988: 83-84) Although the framework above was used and two methodological techniques were employed decision to carry out the initial data collection using questionnaire survey, is not a typical ethnographic technique.

A naturalistic approach to the fieldwork was taken using both qualitative and quantitative procedures.

**6.6 Questionnaires**

There are two main reasons for carrying out a survey using questionnaires. First they are:

- an efficient method of obtaining information from people by asking questions;
- [second] sampling procedures… allow a relatively small number of such people to represent a much larger population. (Schuman & Presser, 1981:1)

Secondly a questionnaire has advantages over other survey methods such as interviews, for:

- it is relatively easy to make contact with people
- a large sample is possible
- it can be completed easily
- there is less interviewer bias
- it is easier to tabulate
- people are familiar with questionnaires
- uniform questions are presented
- it can point out trends for further study
- there is less cost in time and travel.

6.7 Questionnaire Design

Relevant literature was consulted and the many pitfalls which render the questionnaire responses unrepresentative of respondents’ views and/or unrepresentative of a wider population were taken into account in designing the questionnaires. Decisions have to be made about the format for responding, whether the questions are to be closed or open-ended and how the questionnaire is to be circulated and to whom. Respondents can be influenced by the appearance of the questionnaire, the way questions are worded and the order in which questions are presented (Youngman, 1982:3).

Detailed explanation in a question or wording the question in emotional terms can mean respondents are influenced or encouraged to respond in a particular way. Such questions are said to be leading questions and introduce bias. Schuman and Presser (1981) note that those respondents affected by the format are usually ‘the less well-educated’. All the respondents in this survey would be well educated being qualified educators or scientists. Any designer using survey methods should consider whether the recipients are qualified to answer the questions (Berdie and Anderson, 1974:14). Some respondents may not feel qualified to answer certain questions, e.g. research scientists and engineers on school questions. Bearing in mind this restriction it was thought that a limited number of such questions could be included.

It seems obvious that the aim is to achieve reliability so that a questionnaire item consistently conveys the same meaning to the readers. However reliable the questionnaire the data will be affected by variation in factors relating to the respondents e.g. a person’s answers may vary from day to day (e.g. some interviewees
said they might have replied differently if I had come to the school on another day). A person's interpretation of the same question may be different each time he or she reads it. Nevertheless it is important to ensure that questions elicit the intended information.

If the question does not present a single image of meaning for a given person, we cannot be sure which meaning of the question the respondent had in mind when he answered the question. (Berdie and Anderson, 1974 :13)

By aiming for a relatively large sample and response rate some of these discrepancies in responses may be reduced. Sudman and Bradburn (1974), note that a major reason for choosing a questionnaire survey is the possible sample size for the smaller the relative proportion of missing information, the larger the sample, and the more random the missing information, the less troublesome the missing data problems. Practical ways forward suggested by Berdie and Anderson (1974) proved helpful for example: 'decide upon the goals and become thoroughly acquainted with the topic before actually commencing the questionnaire design', and 'know the people who will be surveyed', for, echoing the point made above, people may be hesitant to admit ignorance when a question assumes they know the relevant background information. In order to know the people the authors suggest the researcher should solicit information from potential subjects and other knowledgeable persons. The number of questions, the cost of printing and distribution, and the means of sampling must then be considered. The question "What constitutes an adequate response rate?" has to be asked.

Questionnaire designers must be cautious about including adjectives and adverbs such as 'several', 'most', 'usually' etc. for vague questions encourage vague answers. Designers are advised to avoid words with vague meanings eg 'population', 'environment', and words that have double meaning eg 'liberal', 'conservative'.

It is also better to hand out questionnaires rather than post them and the time for handing or sending out the questionnaires is carefully considered. All surveys should attempt to sample non-respondents, for merely increasing the sample size will not solve
the response rate problem: it will only increase the number of respondents and will not increase the percentage of respondents. It is courteous to send an accompanying letter is sent with the questionnaires which assures respondents that the responses will be handled professionally and which guarantees confidentiality. The letter should include information about a contact person for any queries and should also explain the purpose of the questionnaire and why the person should cooperate. Interestingly Berdie and Anderson (1974) suggest that one should not mention the research is connected with a thesis for people may feel that it is not important to respond to thesis questionnaires.

Questionnaire length need not interfere with response rate (Berdie, 1973; Champion & Sear, 1969) More crucial are relevant, interesting questions.

The major reason for using questionnaires was to clarify the research questions which would be later explored at interview. The views of a cross-section of educators would be helpful in doing this, and for practical reasons such as cost and time, a questionnaire survey seemed appropriate. Frequency counts and cross-tabulations could be carried out using the SPSS data handling software. Collecting information in this way would be like 'describing the tip of an iceberg'; more probing techniques such as in-depth interviews would be needed to investigate the "submerged portion" (Posner, 1981: 12)

6.8 Interviews

A research interview is a two-person conversation, initiated by the interviewer for the specific purpose of obtaining research-relevant information, and focused by him on content specified by research objectives of systematic description, prediction, or explanation. (Cannell & Kahn in Lindzey and Aronson, 1968: 526)

Using interviews the respondent is asked to provide information about himself, his experiences, his perceptions, or his attitudes. In the study educators will be asked about their beliefs about science and technology and about perception about education.

The quality of the information obtained from the interviews will depend in part on the
"competence with which the interview questions are phrased and the way in which the interviews are conducted" (Cannell & Kahn in Lindzey and Aronson, 1968: 529) for "interviewing is an art form as much as a research technique" (Parlett, 1978:4)

There are different ways of approaching interviews; they may be structured, semi-structured or unstructured. The degree of structure within any interview has to be appropriate, there are no correct procedures to follow. Parlett illustrates this:

a very shy and uncommunicative [person] may need a more structured approach;...a fixed set of questions...for an articulate opinionated and confident [person] these might be seen as extremely irksome by the interviewee and the whole relationship between the investigator and the [respondent] put in jeopardy. (Parlett, 1978:4)

Having established, from the questionnaire survey, areas for discussion with interviewees, the decision had already been made to undertake interviews. This decision was also justified considering that the researcher must have some working hypotheses which are contextualised in order to substantiate theory (Byrne, 1990).

Carrying out interviews in a semi-structured form, means that there is inconsistency in questioning. Part of this inconsistency is an inevitable consequence of the characteristics of the respondent eg memory, level of education, response sets (Alwin, 1978). Inconsistency is increased if open-ended questions are used. Closed questions restrict responses to those germane to the researcher's aims and provides data in a form that is easier to code and analyse and may also enable standardisation when they are worded in the same way and presented in the same order (Brenner, 1981:2).

Open questions do not limit the alternatives within the investigator’s frame of reference and they also avoid suggesting or imposing answers the respondent may not have considered (Schuman & Presser, 1981:8). Open ended questions allow people to respond freely and are particularly useful "when one is interested in people's perceptions, beliefs, opinions and motivations" (Pope and Gilbert, 1986 : 21). The areas to be investigated identified with the research questions would be used in...
open a way as possible.

Cohen and Manion (1989) noted that the interviewer may see the interview as a means of pure information transfer when accurate data is obtained if the interviewer asks questions in an acceptable manner and the people giving the responses are co-operative and sincere in their responses. Another perspective sees the interview as a:

transaction which inevitably has bias which has to recognised and controlled.

The third view is that the interview is an encounter necessarily sharing many of the features of everyday life. (Pope and Gilbert, 1986: 18)

Whatever the perspective it is acknowledged that there are problems of bias. If the interview is viewed as pure information transfer, then the interviewer tries to overcome bias by building in questions which test the consistency of a person’s response and act as lie detectors. If the interview is seen as a transaction, the inevitability of bias is accepted and controls are used. These may be the use of a number of interviewers with different biases.

The interview may also be regarded as a shared encounter. In this case the interview data is not subjected to controls for bias: the interpersonal encounter which occurs during an interview is in itself the only valid data.

This latter perspective seemed consistent with an informal, conversational approach. To facilitate the conversation the interviews would be audio-recorded with the minimum of note-taking and comments pertinent to the context would be written immediately after the interview.

Any personal interaction will necessarily be interpreted subjectively. This is inevitable for:

1. Many factors inevitably differ from one interview to another, such as mutual trust, social distance and the interviewer’s control.

2. The respondents may feel uneasy and adopt avoidance tactics if the questioning is too deep.
3. Both interviewer and respondent are bound to hold back part of what is in their power to state.

4. Many of the meanings that are clear to one would be relatively opaque to the other, even when the intention is genuine communication.

5. It is impossible, just as in everyday life, to bring every aspect of the encounter within rational control. (Cohen and Manion, 1989:245)

By making the interviews as informal as possible and by using triangulation methods it was hoped that some of this subjective bias could be overcome.

6.9 Triangulation

Cross-checking is important for data collection and interpretation. The use of two or more methods of data collection is one aspect of triangulation (Cohen & Manion, 1989: 269). The need to check the validity of propositions and hypotheses is inherent in triangulation.

   Exclusive reliance on one method...may bias or distort the researcher's picture of the particular slice of reality he is investigating.

   (Cohen and Manion, 1989:269)

Triangulation forces the observer to combine multiple data sources, research methods, and theoretical schemes in the inspection and analysis of behavioural specimens. (Denzin, 1978:177)

While feeling uneasy about identifying educators as specimens, the relevance of using a number of research techniques for inspection of beliefs is acknowledged for as Denzin (1978) note "playing each method off against each other...maximises the validity of the field efforts." (ibid:304)

6.10 Content Analysis of the Interview Transcripts

Researchers carrying out content analysis must guard against reading 'between the lines', any explanations must be clearly attributed to the text.

   the basic problem facing the researcher who sets out to analyze open-ended
material is that she/he has to classify data on which very little order has been
previously imposed, the first pre-requisite is that the analyst must let the data
"do" the work... That is the proof for or against a certain hypothesis, or the
evaluation of an hypothesis, must arise out of the data, and it must guide the
analyst to revise ideas or discover new hypotheses. The data must also be used
to support any conclusions drawn in the form of quotations. (Mostyn in
Brenner et al 1985:132)

Categorising or coding is an essential part of analysing the text, or analysing the content
of material collected during the research. Content analysis is any technique for making
inferences by systematically and objectively identifying specified characteristics of
messages. (Holsti in Lindzey and Aronson, 1968)

Holsti identifies characteristics which define content analysis: objectivity, system, and
generality. To have objectivity the analysis must be carried out using formulated rules
which if used by others on the same text, would result in the same findings. Systematic
analysis refers to the inclusion or exclusion of content according to certain criteria.
Acknowledging that all research is value-laden, the researcher must be aware of the
illicit coding which she/he has, and must be wary of excluding certain aspects because
they do not fit with his/her hypothesis or of including only aspects which do fit.
Generality means that findings have theoretical relevance.

...purely descriptive information about content, unrelated to other attributes of
content or to the characteristics of the sender or recipient of the message is of
little scientific value. (Holsti in Lindzey and Aronson, 1968:598)

Cohen and Manion (1989) cite the example of checking the outcomes of a questionnaire
survey with observational study. As impressions are formed the researcher checks them
out by triangulation techniques, put another way:

Get the bearings of others (which might be interpreted as including the values
and beliefs of others), there is a need to have more than one reference point,
including one’s own, and more than one method. Interpretation of oneself and
others, through many sources and through qualitative as well as quantitative
6.11 Summary

The format for the research can be outlined as in the Figure 6.1 on the next page. The main research tool will be interviewing and content analysis of the interview data. Questionnaires will also be used which will be quantified, for as Holsti concludes after discussion of qualitative techniques for most scientific research, "the advantages to be gained by some type of quantification continue to be important." (in Lindzey and Aronson, 1968 :600)
Figure 6.1: Research Format

Selection of project
(Values issues in Technology education)
Learn something

(By reading and discussion)
Ask descriptive questions

(First questionnaire)
Carry out analysis

Check interpretation
(in writing and in discussion)

Collect more data

Ask descriptive questions
(Piloting further questionnaires)

Analysis

Collect more data
(Final questionnaire)

Analysis
(Using SPSS)

Ask structural questions
(In depth interviews)

Analysis and interpretation
(Check coding with colleagues)
CHAPTER 7  METHOD AND PROCEDURE

7.0 Field Work Plan

This study is concerned with the beliefs held by science and technology educators, hence the target population was automatically identified but samples still had to be chosen from this large population. To give as representative a picture as possible, I decided to contact people at all levels of education, primary, secondary, tertiary and higher education. The inclusion of higher education enabled the views of people working in initial and continuing teacher education to be explored along with those of science and technology teachers. Practising scientists and engineers involved in teaching undergraduates and postgraduates, could also be included. An added bonus was that four of the latter were directly involved with school/industry liaison.

Interviewing using open ended questions was the main research tool, for interviews are the most appropriate means to probe people's beliefs (Pope and Gilbert, 1986). The questions to be asked at interview would be identified from the analysis of a questionnaire survey [Appendix 5]. Some of the disadvantages of questionnaire surveying, such as the possibility of receiving unrepresentative responses; of having a low response rate; and not being sure who would complete the form (Berdie and Anderson, 1974) were realised but I thought that by targeting educators and given that the interviews would be the prime source of data, doubts about reliability and validity of questionnaire responses could be considered to be acceptable.

Sampling depends on the research methods to be used and frequently on pragmatic reasons such as cost in time and money. The number of questionnaires to be printed was influenced both by financial considerations and by assessing what would constitute an acceptable response. At the initial stage of designing the questionnaire, the researcher must address the ways in which the survey will be analysed (Youngman, 1982). I realised that a questionnaire which consisted of closed questions could be analysed using SPSS and therefore except for entering the data into the computer, the number of returns which could be handled was not limited. If, however, open
questions were used the number of response sheets which could be read adequately by
one person was limited. With the exception of the first questionnaire, decisions about
the size and nature of the sample were not made until after the final questionnaire was
produced.

7.1 Designing the Questionnaires
The first questionnaire [Appendix 1] was devised without reference to the literature or
to colleagues in January 1991, and in February 1991 it was given to 16 people.
Twelve were returners to science teaching attending the university for a refresher one-
day course. All had science and education qualifications and had taught science in
middle or secondary schools. Four colleagues were also given the questionnaire.

After the respondents had completed the questionnaire, I discussed the format with
them. From the analysis of the responses and from the verbal comments, I realised that
the wording of the questions, the words to be used in the questions and the method of
eliciting the responses had to be examined. Also respondents needed a number of
options when responding. Questions about personal details were not asked. Some
people said they were unhappy about the use of the word 'truth' and the word 'fact',
but for reasons explained in chapter 5 these were retained in all subsequent
questionnaires.

The lessons I learned from the experience of producing the first questionnaire were
valuable and, although the questionnaire was unsatisfactory, comments from respondents
proved useful in later versions. The findings from this first questionnaire are included
in the analysis.

The second version [Appendix 2] covered many of the same areas particularly those
pertaining to beliefs about science. In addition it included statements on gender and
science (see Qs 9, C1, C2, C3,C4,) and statements about values (see Qs 12, 6). A
Likert scale was used for responses (Strongly Agree, Agree, Disagree, Strongly
Disagree) with respondents asked to circle the appropriate words. This draft
questionnaire was never used or trialled. It was designed during August 1991 and was
intended to be trialled in September 1991. Due to unexpected and chance circumstances this second version was shown to Prof Fensham during August 1991. Fensham suggested the material from a Canadian survey on high-school graduates' beliefs about science technology and society, (known as VOST - Views on Science and Technology) would be useful (Aikenhead, et al, 1987). Reading this material increased my motivation and provided the basis for subsequent questionnaires.

The format of the VOST booklet was adapted for the next few versions of the questionnaire which now consisted of statements about the nature of science, technology, values and education with a mixture of Likert scale responses and open questions. In the VOST booklets students were asked to "agree or disagree with the statement or say that they 'can't tell' in order to establish a particular position from which they could explicitly argue". Every VOST statement had either a converse statement eg:

2.1 Most Canadian scientists are concerned with the potential effects (both helpful and harmful) that might result from their discoveries.
2.2 Most Canadian scientists are not concerned with the potential effects (both helpful and harmful) that might result from their discoveries.

or an opposite statement, for example contrasting a democratic view with a technocratic view:

1.1 Scientists and engineers should be given the authority to decide what types of energy Canada will use in the future (e.g. nuclear, hydro, solar, coal burning, etc.) because scientists and engineers are the people who know the facts best.
1.2 Scientists and engineers should be the last people to be given the authority to decide what types of energy Canada will use in the future (e.g. nuclear, hydro, solar, coal burning, etc.) because scientists and engineers are the people who know the facts best.

Sometimes several views needed to be expressed eg:

19.1 Earning a decent salary is really the main motivation of most Canadian scientists. (deals with the role of financial gain)
19.2 Earning recognition from other scientists is really the main motivation of most Canadian scientists. (deals with the role of recognition)
19.3 While earning recognition is important to Canadian scientists, the most important thing is for them to satisfy their curiosity about natural phenomena. (deals with the role of satisfying curiosity)

7.2 Developing the Final Questionnaire.
Many statements from the first two questionnaires were included in the final version although some were changed in interim versions. For example: "Science is about observing and explaining the world", became "Science tries to explain observations about the universe".

Some of the statements from the early versions were not included in later versions: "Science is superior, prestigious knowledge." By asking people to comment on "Science is different from other areas of human thought", it was thought that there would be greater opportunity to explore understandings and beliefs about science.

In the early days of the study, while reading about science and metaphysics, it seemed this might be an area to explore, hence the inclusion of statements such as "Superstition has nothing to do with science." "Astrology has nothing to do with science" and questions about metaphysics on the first questionnaire. Such statements were removed for three reasons. First people did not understand the word metaphysics, second the questions about astrology and superstition did not help to probe understandings about metaphysics, and third metaphysics was unlikely to be a crucial issue in the matter of education and values pertaining to science and technology. 'Refutation' was also a word that was not understood and hence this statement was changed. Many of the statements from questions 4 to 9 on the first version were adapted and used in questions 1 - 14 of the final version. [see Appendix 5]

From September to December 1991 I continually redesigned the questionnaire [Appendix 3]. Subsequent versions were not only adaptations of the VOST statements but also adaptations of the format of the VOST booklets. Two of the drafts had statements followed by their converse statements. Versions 3 - 5 required people to respond to the statements either by adding a tick or cross or by underlining on a Likert
scale. Two of the drafts asked for additional responses, leaving space for people to write what they wished. These three versions were given to five colleagues, one of whom has considerable experience in questionnaire design. Comments were mainly about the length of the questionnaire and the unnecessary inclusion of positive and negative forms of the statements. From the analysis of this version, the inclusion of positive and negative statements seemed to be serving no purpose, i.e. there was no discrepancy in the answers to the positive and corresponding negative statements. In the light of colleagues' comments and the evidence of lack of benefit of such a format, positive and negative statements were removed and hence the questionnaire was shortened.

The two versions 6 and 7 were given to another 12 colleagues. Alterations were suggested regarding the wording of some statements and the instructions for completing the questionnaire. It was interesting that although invited, no-one added comments in the spaces provided and that few people used the "strongly agree" or "strongly disagree". Many people said they preferred to tick boxes. Three people said they did not understand what was meant by 'values'. The statements about technology were queried - it was noted that people did not understand what was meant by 'technology'. The main changes in version 8 were in the wording of the gender questions and the inclusion of an explanation of values. The version had only two response categories - agree and disagree. This was an oversight. In response to comments about this version, the ninth version was produced and again trialled.

15 copies were sent out and eventually 13 were returned. Two respondents said the questionnaire was too long and difficult to complete. Two did not attempt the questionnaire but commented that it was impossible to do. It was clear that there was still confusion about what is meant by science and technology and values. Considerable thought was given to the response category 'neither agree nor disagree'. This could mean the person was neutral regarding the matter but I felt that such a response would not allow for lack of knowledge or partial agreement. There is always a dilemma about introducing a 'middle' category. There is evidence that inclusion substantially increases the number of 'don't knows' by making their legitimacy clear (Schuman & Presser 111
1981:39). The middle category was changed to 'undecided' which it was hoped would be chosen by people who could not decide on the other two categories for whatever reason.

The final questionnaire consisted only of closed questions. The advantage of doing this is that it restricts responses "to those germane to the researcher's aims and provides data in a form that is easier to code and analyse" (Schuman & Presser, 1981:8). Although no open questions were used, respondents were encouraged to write additional comments on the questionnaire and many did this.

The effect of the order of the questions is probably the most frequently offered explanation for an unexpected or unreplicated survey finding (ibid:24). To present a smooth order of questionnaire usually means asking questions relating to similar areas together. This was the pattern adopted on the final questionnaire. Questions were changed and grouped in categories: science, technology, scientists, values education and decision-making. This grouping allowed a paragraph to be included giving an explanation of values. Without this explanation I thought that people would be unable to respond to questions about the inclusion of values in their teaching.

Note was taken of criticism of particular questions on version 8 and changes were made [details are given in Appendix 4]. By changing the questions, in particular forgoing the use of positive and negative versions of statements, the opportunity to cross-check was lost. However, I thought that this had to be sacrificed in order to shorten the questionnaire and to address the frustration experienced by many respondents at the inclusion of two very similar statements.

The final questionnaire [Appendix 5] had 38 questions including 5 relating to personal details. The questions were all coded using numbers 1-80. Questions were divided into 4 sections: Questions about Science, Questions about Technology, Questions about Science and Technology, and Questions about Values and Education. Respondents were asked to tick only the boxes which applied to the statement and were given the choice
of three responses for each statement - Agree, Undecided and Disagree.

7.3 Contacting Potential Respondents
Of the five hundred questionnaires printed, a total of 420 questionnaires were sent to people concerned with science and technology education in schools, tertiary and higher education colleges and a university (Surrey) during February 1992. Those at the university were chosen at random by taking the name of every sixth person with the title Dr or Professor from departments concerned with science, engineering or technology.

Letters were sent to Directors of Education in a number of Local Education Authorities asking for permission to contact some of the schools in the LEA [Appendix 6]. A questionnaire was included with the letter. After permission was obtained, I sent letters to headteachers in a number of schools [Appendix 7]. This letter asked him or her to give the enclosed questionnaires and covering letters, to science and technology teachers in their schools. Stamped addressed envelopes were included for the return of the questionnaires or replies.

The selection of schools and colleges to receive the questionnaires cannot be described as completely random: certain counties and boroughs (Lancashire, Hampshire, Kingston, Lancashire, Merton, Richmond, Surrey and West Sussex) were selected, for practical reasons. The questionnaire asked respondents to agree to be interviewed. In order to carry out interviews with the minimum of cost, both financial and time needed, the schools and colleges had to be easily visited. Lancashire was chosen in order to sample another area of the country. Schools and Colleges were selected from the Education Year Book for the U.K., 1991. The selection contained both state and independent schools and colleges.
### Numbers of Questionnaires sent

<table>
<thead>
<tr>
<th>Number of schools</th>
<th>Total number of questionnaires</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hampshire primary schools</td>
<td>24</td>
</tr>
<tr>
<td>Hampshire secondary schools</td>
<td>15</td>
</tr>
<tr>
<td>Lancashire primary schools</td>
<td>22</td>
</tr>
<tr>
<td>Lancashire secondary schools</td>
<td>18</td>
</tr>
<tr>
<td>Surrey primary schools</td>
<td>38</td>
</tr>
<tr>
<td>Surrey secondary schools</td>
<td>24</td>
</tr>
<tr>
<td>Kingston, Merton, Richmond, and Sutton secondary schools.</td>
<td>9</td>
</tr>
<tr>
<td>Colleges of further education</td>
<td>10</td>
</tr>
<tr>
<td>University of Surrey</td>
<td>25</td>
</tr>
<tr>
<td>Technology education conference</td>
<td>10</td>
</tr>
<tr>
<td>ASE annual meeting</td>
<td>10</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>19</td>
</tr>
<tr>
<td><strong>Total number of questionnaires sent</strong></td>
<td><strong>420</strong></td>
</tr>
</tbody>
</table>

#### 7.4 The Response to the Questionnaire

Questionnaires were sent to respondents by post. The response to a mail questionnaire is generally recognised as being smaller than if a personal approach is used (Alwin, 1978). This had to be balanced against the size of the sample which would have been possible if a personal approach had been made: 211 responses to the questionnaire would not have been possible. The response rate of 50% could have been increased by sending reminders or chasing letters, or second copies of the questionnaire. This was not possible for I did not know to whom the headteacher had given the
questionnaires. Further questionnaires and letters could have been sent to the schools but this might have caused antagonism by adding to the work of overburdened teachers.

7.5 The Interviews

Although the questions to be asked at interview were identified following preliminary analysis of the questionnaire, the interviews would be unstructured so that people would be able to express themselves at length. By approaching the interviews with a check list of topics to be addressed, I hoped that the comments made would be relevant to the research area.

Having decided to carry out unstructured interviews using open-ended questions, the next points to be addressed were:

a) What are the questions to be asked? These were basically the research questions identified earlier in the research (see Chapter 5) but modified in the light of preliminary analysis of the questionnaires.

b) How many people are to be interviewed at one time?

c) Who might be interviewed?

d) How is the interview to be recorded?

e) Where is the interview to be recorded?

a) The Interview Questions

Carrying out unstructured interviews means inconsistency in questioning. Part of this inconsistency is an inevitable consequence of the characteristics of the respondent eg memory, level of education, response sets. In the actual interviews sometimes the person interviewed had little understanding or experience of scientific method and it was pointless to pursue questioning in this area. In the same way research scientists and engineers had little knowledge of school education. Before undertaking the interviews a list of possible questions was drawn up. These questions arose from the analysis of the questionnaire data and they are listed in section 8.2.11.

Although the interview questions were written down they were rarely presented in any particular format but were posed in a way which seemed appropriate to the circumstances e.g. the understanding and level of interest of the person being
interviewed. In some cases the questions had to be further explained, sometimes the interviewee was referred to the questionnaire. Not all the questions were used and there was great variety in the questions which were used in specific interviews. The interviewer had the interviewee's copy of the completed questionnaire and the interviewee had a copy of a blank questionnaire.

b) Single or Group Interviews?
I knew group discussions would be a possible way to obtain data about people's beliefs. Such a discussion would be a form of group interview which could be unstructured using open-ended questions. After discussion with colleagues, group interviews were discounted for a number of reasons. Skills relating to facilitation of groups and research skills would be needed. I considered myself unable to act as both facilitator and researcher. Without skilled facilitation the discussion might not address the issues. It was possible that facilitation could be provided by another person, thus allowing me to concentrate on data collection, but this was still problematic. Assuming a suitable person could be found, it would mean a considerable time commitment for them. There are three ways to collect data at group interview, by taking notes, audio recording and video recording. Note taking by itself seemed impossible unless it was merely to record my impressions as an observer. This was too subjective, actual responses in written form were needed for analysis. Experienced researchers indicated the potential difficulty of identifying unfamiliar voices on audio or video tape unless people identified themselves before speaking, spoke one at a time and allowed time for the camera to focus on them. This could restrict a free exchange of views as indeed might the presence of cameras. With a number of appropriate cameras and experienced camera operators these problems could no doubt have been overcome but such facilities were not easily available. In addition to this the author lacked experience in analysing both types of tapes.

It is important to create an environment in which people feel comfortable and free to speak of their beliefs if a group discussion is to be successful. This can take time to achieve and depends not only on the facilitator but also on the participants. Speculation about the people to be brought together led to the realisation that choice of groups
would also be problematic. I also thought that the presence of university research scientists and engineers could discourage school teachers from expressing their views. Similarly primary teachers might feel restricted by the presence of teachers in sixth forms. For these and other pragmatic reasons concerned with the cost of bringing people together with the necessary equipment, other research approaches were taken although I never completely ruled out the possibility of group discussion.

Before undertaking any interviews for the actual thesis, I carried out practice interviews with colleagues and relatives. The audio tapes were then transcribed and discussed with interviewees. One of the thesis interviews took place with two people, at their request.

c) Who might be interviewed?
The people who could be interviewed identified themselves by responding to a request at the end of the final questionnaire. Approximately 80 offers for interviews were received so a selectivity exercise had to be carried out. Interviewees were selected for representation and pragmatic reasons.

The aim was to have at least two people from each sector of education - primary, secondary, tertiary and higher education - who are involved in teaching science, technology and engineering along with science and technology educators and research scientists and engineers involved directly with schools or with undergraduate or postgraduate students. The pragmatic reasons were related to cost in both time and money, of travelling to the venues for the interviews. Twenty-seven interviewees were selected and contacted by letter suggesting possible times for interviews [see Appendix 9]. Letters were sent to all those who had volunteered for interview thanking them for the help but pointing out they would not be contacted as too many offers had been made [see Appendix 9].

d) How was the interview to be recorded?
Although the length of the proposed interview was given on the questionnaire, the format of the interview was not specified. Interviews were audiotaped and permission to do this was negotiated at the time the interview was carried out. Interviewees were
assured of anonymity. After transcribing the tape was wiped clear and names were not written on the transcripts.

e) The Locations for the Interviews
All the interviews were carried out at the place of work of the interviewee. Within schools the place for the interview was chosen by the interviewee, interviews at the university took place in the interviewee’s own room. In all cases the environment was reasonably comfortable, coffee was usually provided and the interviewee and I sat around a desk or table.

All the interviews took place in an atmosphere of friendly and enjoyable discussion and on being thanked for their time many people said they had enjoyed the session. There was never any apparent distress or defensiveness on the part of the people interviewed. This may be partially due to the fact that the questions were not sensitive or personal ones. As far as possible, I kept my input to a minimum and respondents were allowed to say what they wished without interruption. I tended to make "um " noises, nod my head and smile while listening to the respondent. Interview sessions were usually between 45 and 90 minutes in length and took place at the end of the school or college day or at any time convenient to university people. Only one interview per day was usually carried out, occasionally two.

7.6 Analysing the Tapes
I listened to each audio-tape once without stopping the tape, usually in the evening of the day the interview was carried out. Having become familiar with the respondents voice, I transcribed the tape over the next two or three evenings using a memo-scriber machine. I produced verbatim transcripts of interviews and read each transcript through with the ‘macro’ research questions in mind. In doing this I gained an understanding of the areas covered in each interview and made a note of these along with any potential overlap. Thus for example, responses to questions such as " What is technology?" sometimes included elements which might be grouped under beliefs about science or within gender differences regarding science and technology. At this stage the ‘notes’ were sometimes mental ones.
Each group of responses corresponding to a 'macro' question group was then taken and read and broad categories of responses identified. By cutting the transcripts I was able to physically group responses into categories. In deriving these further categories the interview questions were important but often the interviewees' own descriptions and comments became the basis of the categories. At this point I transferred each group of responses onto disk in word-perfect format. The responses were written verbatim. By copying responses it was possible to include the same comment in other categories. The list of comments in each category was then printed. With these as a guide and with constant reference to the original transcripts, a summary discussion of each category was written which was part quantitative. It was quantitative in that the number of the same or close comments from the interview data was included along with the quantitative data from the questionnaires. In addition any appropriate responses to the open questions in the first questionnaire were included.

Copies of the complete transcripts were given to three colleagues and they independently grouped the responses. They were not given the research questions. There was mutual agreement on the major groupings, with similar insights about interpretation. Although there were no discrepancies in the groupings, colleagues identified additional groups e.g. some interviewees seemed to be describing an inductivist approach to science, others a Popperian (see Chapter 3). Individual colleagues commented that they felt that their personal interests had led them to look at some areas more closely than others. For instance the one female colleague was interested particularly in the gender responses and the comments about scientific models. Another male colleague was interested in the responses regarding teaching methods. Comments from colleagues are included in the summary of the data which follows.

7.7 Summary

After attending research methods courses, discussing with colleagues and consulting the literature, I decided that interviews were the only realistic way of probing people's views. I felt, however, I could not carry out interviews without focusing the questions to be asked. The discovery of the VOST questionnaires (see section 7.1) was a great help to me for the issues investigated and the statements included in the Canadian
questionnaire were similar to those I wished to explore. I realised a questionnaire would help me to identify the questions to ask at interview and would also provide a way to approach possible interviewees. Finding the VOST questionnaire also gave me confidence to proceed with the research; it seemed that I was asking important questions.
CHAPTER 8 PRESENTATION OF THE DATA

8.0 Introduction

This thesis is concerned with beliefs about science and technology and with how such beliefs influence the inclusion of values in science and technology education. The research is essentially about the teaching and learning of technology and science with students from 5 years of age through to postgraduates, and the research sample has therefore, involved science and technology educators. By including teachers in university departments the sample has drawn in people involved in research which has given the research a wider perspective and allowed the views of non-researching educators to be compared with those involved in research in science and technology.

Following the literature survey, two broad areas for investigation were identified:

1. Science and technology educators' beliefs and perceptions about science and technology,

2. The inclusion of valuing and awareness of value judgements in decision-making within science and technology education.

Chapter 7 outlined the process used. The final questionnaire (Appendix 5) served two purposes: it enabled quantitative data to be obtained, e.g. the percentage of people who think value judgements only enter into technology when decisions are made about how the technology is to be used, but, more importantly, it provided a means of identifying the questions to be asked at interview. Given that the research was concerned with the exploration of people's beliefs, interviewing was considered to be the most appropriate research technique (see section 6.8).

This Chapter presents the quantitative data from the questionnaires, which is then used to identify the questions to be used during the interviews. The last sections of the Chapter present the interview findings.
8.1 Questionnaire Data

The data is drawn mainly from the final questionnaire (Appendix 5). Any comments from the first questionnaire, devised in 1991 and given to sixteen people, (see Appendix 1) which differ from the responses in the final questionnaire will be included in square brackets. Analysis of this questionnaire is given in Appendix 8. Any statistically significant responses from the sample are included in the ensuing text.

Frequency counts and statistical analysis of the responses to the final questionnaire were carried out using SPSS. These are included in Appendix 11.

8.1.1 Personal Details of Respondents to the Final Questionnaire

Figure 8.1

Sex of respondents

<table>
<thead>
<tr>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>108</td>
<td>90</td>
<td>211</td>
</tr>
</tbody>
</table>

Not replying = 13

Figure 8.2

Ages of respondents

Not replying = 23
It became apparent that the majority of respondents were in the age group 40-49 years, and half were over the age of 40. This occurred by chance. Using SPSS the statistical relationship between age and particular responses was examined but was found not to be significant.

Figure 8.3

Responses to Question 35 "I have qualifications related to"

<table>
<thead>
<tr>
<th>Subject</th>
<th>Number of people</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>62</td>
</tr>
<tr>
<td>Technology</td>
<td>34</td>
</tr>
<tr>
<td>Physics</td>
<td>54</td>
</tr>
<tr>
<td>Chemistry</td>
<td>62</td>
</tr>
<tr>
<td>Biology</td>
<td>57</td>
</tr>
<tr>
<td>Engineering</td>
<td>16</td>
</tr>
<tr>
<td>Education</td>
<td>122</td>
</tr>
</tbody>
</table>

(NB: The total is greater than 211 because some people ticked more than one box.)

Given that the research concerns the inclusion of values in science and technology teaching, the range of qualifications suggests that the sample is an appropriate one although the number of people concerned with technology is proportionally low.

Figure 8.4

People actively involved in science or engineering research

Number of people involved in research = 28
Percentage of people involved in research = 13%

Given that the primary aim was the exploration of the views of those people concerned with science, technology and the education of 5-18 year old students, it is not surprising that the percentage of educators involved in research is low. The statistical analysis revealed some significant differences in responses between those people involved in
research and those not involved. These differences are included in the presentation of the data.

Figure 8.5

**Areas taught**

![Pie chart showing areas taught]

Figure 8.6

**Age range of students taught**

![Pie chart showing age range of students taught]
8.1.2 Responses to Statements about Science

Unless stated otherwise the data will refer to the final questionnaire.

Ninety-four percent of the respondents thought that science tries to explain observations about the universe. From the fact that relatively few respondents (24%) agreed that "given sufficient time, science will be able to explain all known phenomena", the view is that scientific explanations are, and always will be, restricted to some situations and experiences.

One aim of the research was to try to find the picture of science respondents hold. Most people thought that science was not different from other areas of human thought, with only 27% of the sample agreeing that it was different. The fact that significantly more men, physicists and teachers of science thought this suggests that further research in this area would be useful (Appendix 13 Table 4). [Only one person out of sixteen on the first questionnaire agreed that science is superior, prestigious knowledge and no one that "science is the only way to explain the world we experience"] Relatively few people (39%) believe that "Science is the most adequately tested medium of explanation" although 41 % were undecided. Again more men, physicists, and teachers of science thought this (Appendix 12, Table 4). Far more people (68%) thought that science is concerned with making precise measurements. The restricted remit for science is reinforced by the above responses. Perhaps it is restricted to phenomena that can be measured.

Figure 8.7 suggests that respondents thought that in order to explain the world, scientists observe, collect data, carry out analyses and tests, and formulate explanations and hypotheses. Statements on the questionnaire were presented in such a way that, in addition to exploring the processes thought to be followed by scientists, they could, in a limited way, give some insight into different views about methodological approaches such as inductivism or hypothetico-deductivism.
People see the inductivist approach to be most typical of scientific investigation with fewer people acknowledging the role of what might be called an hypothetico-deductive approach. It must be noted that the majority of the respondents thought that scientists adopted all of the approaches, with 47% of the sample believing that scientists are flexible and adaptable in the way they work and are willing to try many different methods. The statement about scientists trying to disprove their theories was an attempt to explore ideas about Popperian falsifiability. There is some indication that respondents think that scientists try to prove rather that disprove their theories.

8.1.3 The role of instinct and intuition

Slightly more people consider instinct and intuition to be important (39% agreed) in comparison with those who do not (26%), with 35% undecided. [All sixteen respondents to the first questionnaire believed these characteristics to be important in scientific work.] It should be noted that significantly more researchers see instinct and intuition to be important (Appendix 12, Table 6).
8.1.4 Facts, proof and science as truth

Only 16% of those responding to the final version agreed with the statement: "When scientists carry out investigations correctly they discover facts that will not change in future years." Four people wrote on the questionnaire that they were unhappy about the word 'facts' saying

"Define facts"

and

"Scientists do not discover facts".

It is interesting that although some respondents were unhappy about facts a large number (82%) of the respondents believe that scientists try to prove their hypotheses. Three respondents wrote on the questionnaire that they were unhappy with the word 'proof'. Both questionnaires contained statements about science and truth. Sixty-nine percent of respondents to the final questionnaire thought that scientists are concerned with finding the truth. [Four people wrote on the first questionnaire that scientific laws can be said to be true only with reference to current knowledge, and that the truth is changeable.] Two people wrote their objections to the use of the word 'truth' in the statement on the final questionnaire.

Views about truth link with views about scientific laws. The latter were explored using a number of statements. "Given sufficient time, science will be able to explain all known phenomena" (24% agree) and "When scientists carry out investigations correctly they discover facts that will not change in future years" (16% agree). The low response rates suggest that respondents think science does not produce absolute truth and that there are areas of human experience which are beyond the remit of science. One statement referred to scientific laws: "Science is concerned with discovering the laws of the universe". This was similar to another: "Science tries to explain observations about the universe". Fewer people agreed with the first statement (66%) compared with (94%) agreeing with the second.
8.1.5 Objective and impersonal science?

A number of statements on the final questionnaire, (3, 5, 13.21, and 14.24 - 14.28) were included to enable views about the objectivity of science to be explored. The responses to statements giving reasons why scientists disagree about a scientific matter, suggest that most people think subjective factors are the main reasons for disagreement:

Figure 8.8

<table>
<thead>
<tr>
<th>When scientists disagree about a scientific matter it is probably because:</th>
<th>Agree</th>
<th>Undecided</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>- they have different interpretations of the facts.</td>
<td>92%</td>
<td>6%</td>
<td>2%</td>
</tr>
<tr>
<td>- they are defending their own theories.</td>
<td>66%</td>
<td>21%</td>
<td>13%</td>
</tr>
<tr>
<td>- they must bear in mind the need for support for their research.</td>
<td>53%</td>
<td>26%</td>
<td>21%</td>
</tr>
<tr>
<td>- they hold different moral values.</td>
<td>36%</td>
<td>29%</td>
<td>35%</td>
</tr>
<tr>
<td>- one side does not have all the facts</td>
<td>28%</td>
<td>26%</td>
<td>46%</td>
</tr>
</tbody>
</table>

N=211.

[No one responding to the first questionnaire agreed that "Scientists approach their work objectively, their feelings, wishes and personal attributes have nothing to do with the processes they carry out."] This picture of 'subjective science' is reinforced by the responses to the statement "Scientists are not really influenced by politics because they work in particular institutions and are pretty much isolated from society." Only 9% of the sample agreed with that statement. Six respondents wrote of the questionnaire comments that can be described as cynical e.g. "They do whatever is necessary to ensure success." "They will do any dam thing to get their money." (These comments plus the statistical responses were a surprise to me.)

Asked whether "Scientists choose their area of work because of the possible benefits of their work for society", only 18% of the total sample agreed. There was considerable agreement (93%) that scientists should be concerned with the potential
effects (both helpful and harmful) that might result from their discoveries. This response I saw as contradictory to the belief that the government should give scientists research money to explore the unknowns of nature and the universe (80% of the sample agreed). One possibility might be that respondents think scientists should be allowed to carry out investigations but they should have some concern about, or influence on, the way the knowledge from the investigations is to be used.

8.1.6 Who should make decisions?

Figure 8.9 Responses to the statement: "Decisions about whether nuclear energy is used to produce electricity are made by the following people":

<table>
<thead>
<tr>
<th></th>
<th>Agree</th>
<th>Undecided</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elected representatives and civil servants</td>
<td>92%</td>
<td>6%</td>
<td>2%</td>
</tr>
<tr>
<td>Philosophers, theologians and other academics</td>
<td>3%</td>
<td>20%</td>
<td>77%</td>
</tr>
<tr>
<td>Industrialists</td>
<td>60%</td>
<td>19%</td>
<td>21%</td>
</tr>
<tr>
<td>The public</td>
<td>17%</td>
<td>16%</td>
<td>66%</td>
</tr>
<tr>
<td>Scientists and engineers</td>
<td>46%</td>
<td>19%</td>
<td>36%</td>
</tr>
</tbody>
</table>

N=211
Figure 8.10 Responses to the statement: Decisions about whether nuclear energy is used to produce electricity should be made by the following people:

<table>
<thead>
<tr>
<th></th>
<th>Agree</th>
<th>Undec-</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elected representatives and civil servants</td>
<td>78%</td>
<td>7%</td>
<td>15%</td>
</tr>
<tr>
<td>Philosophers, theologians and other academics</td>
<td>42%</td>
<td>11%</td>
<td>46%</td>
</tr>
<tr>
<td>Industrialists</td>
<td>49%</td>
<td>12%</td>
<td>39%</td>
</tr>
<tr>
<td>The public</td>
<td>80%</td>
<td>8%</td>
<td>12%</td>
</tr>
<tr>
<td>Scientists and engineers</td>
<td>75%</td>
<td>8%</td>
<td>17%</td>
</tr>
</tbody>
</table>

N=211

The changes in the responses between the two tables indicate a desire for more involvement of the public, scientists and engineers, philosophers, theologians and other academics in decision-making. Conversely fewer elected representatives and civil servants and industrialists should be involved. Only 13% of respondents thought that scientists and technologists should make decisions about genetic engineering whereas 75% think they should make decisions about the use of nuclear energy to produce electricity. It should be noted that the two questions were worded differently. For an accurate comparison I should have included some aspect of genetic engineering e.g. the use of genetic engineering in diagnostic screening. Nevertheless I find it interesting that there is such a difference in the response rates and that significantly more biologists are happy that scientists and technologists should make decisions about genetic engineering.

8.1.7 Beliefs about science

To summarise: the questionnaire data indicates that the respondents believe science is concerned with observing and explaining the world but that science is not the only way to explain human experience. Indeed relatively few respondents think science is different from other areas of human knowledge or that it is the most adequately tested medium of explanation. Science is seen to be concerned with making precise measurements. The responses to statements about scientific laws suggest that laws are
not 'out there' to be found or discovered but are devised by scientists. Laws are explanations which are context dependent e.g. are related to historical time, current knowledge and available investigative procedures.

Although some people think scientists are concerned with finding the truth, scientific truth is not seen as absolute. Scientific laws are explanations but few see these as fixed and unchangeable. Scientists are not seen to work in objective, impersonal ways but are influenced by political considerations. Few are thought to choose their area of work in the light of possible harm or benefit to humans although there is considerable agreement that they should. It is interesting to speculate how this belief links with the view that scientists should be able to explore the unknowns of nature and the universe. Perhaps such exploration is seen to be neutral in terms of human harm or benefit, or people might have wished to include a qualifying clause such as 'as long as they are aware of possible effects on humans', the problem being that it is very difficult to work out a cost benefit analysis of an unknown. Recalling the discussion in section 3.14, I think the data is more suggestive of a social constructionist view of science than a positivistic one.

8.1.8 Responses to Questions about Technology

In response to the statement "technology is the application of scientific knowledge", 72% agreed, 15% were undecided and 12% disagreed. A significantly higher agreement rate was found in the responses of teachers of science than other teachers: this was not unexpected. More researchers than non researchers (Appendix 12, table 1). I can offer no explanation for this. Three categories of purpose for technology were explored:

1. Technology is mainly concerned with making and selling goods (16% agree);

2. Technology is about finding appropriate solutions to human problems (84% agree);

3. Technology enables us to control our environment (61% agree).

Significantly more technologist agree (Appendix 12 table 2).
Although 84% of respondents thought that technology is about finding appropriate solutions to human problems and 61% agreed that technology enables us to control our environment, fewer people (24%) thought that we will solve our current environmental problems by the use of new technologies (significantly fewer physicists agree). Asked whether science and technology could offer a great deal of help in resolving social problems like poverty, crime and unemployment, 48% agreed. A related question asked if many social problems like poverty, crime and unemployment are the result of scientific and technological developments: 16% agreed. Over half of the respondents (58%) disagreed with the statement that value issues only enter into technology when decisions are made about how it is to be used. These responses are not easy to understand: there is a general perception that technology is about finding solutions to human problems but that these are not social or environmental problems. Yet technology enables us to control the environment. Although over half the respondents thought technology is value-laden, it is not clear how this is translated into actual human or environmental problems. Given that technology is seen to be concerned with solving human problems, it would be better to invest money in technological research rather than scientific research”. However only 11% agreed.

The majority of respondents (85%) thought technology should be part of all children’s education from 5-16 years with significantly more women agreeing than men. Not surprisingly significantly more technologists (97%) agreed that technology should be part of all children’s education than did science teachers (Appendix 12, table 7). The low response rate supporting investment in technology research is interesting given that technology is seen as a way of solving human problems. This might be understood if technology is seen as applied science and that technological developments are closely linked with, or dependent on, science. Another reason could be that technology is not seen as having a research base.

8.1.9 The Inclusion of Value Judgements in Science and Technology Education. Having read a definition of the word value, respondents were asked to respond to a number of statements.
Figure 8.11 **Including value issues**

<table>
<thead>
<tr>
<th>Social and value issues relating to technological developments:</th>
<th>Agree</th>
<th>Undecided</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>-should not be discussed in school at all.</td>
<td>2%</td>
<td>3%</td>
<td>95%</td>
</tr>
<tr>
<td>-are best discussed in science and technology lessons</td>
<td>15%</td>
<td>25%</td>
<td>60%</td>
</tr>
<tr>
<td>-should be discussed in all areas of the curriculum</td>
<td>90%</td>
<td>9%</td>
<td>1%</td>
</tr>
</tbody>
</table>

If science teachers and technology teachers include discussion about social and value issues in their lessons, industry will be seen in more rational and realistic terms.  

If industry is seen in more rational and realistic terms, this may help to encourage young people into industry.  

N=211

Many respondents think values enter into all aspects of the technology process and, if science and technology teachers include discussion about social and value issues in their lessons, industry will be seen in more rational and realistic terms. This indicates a commitment to the inclusion of values in science and technology education.
8.1.10 Responses to the Statements about Gender
Most people (89%) agree that "In general women and men have the same intellectual abilities which means they are both equally able to be scientists and technologists" and that in general women are reluctant to be scientists and technologists because of the way society has defined the role of women (61% agreed with 16% undecided, and 23% disagreeing. Significantly more researchers agree) There was a mixed response to the statement "men have influenced the way science is done so that it is primarily a masculine activity", with 37% agreeing, 19% undecided and 44% disagreeing. There was no significant differences in the responses between men and women.

8.1.11 Summary of the Questionnaire Data
The main findings from the questionnaire data suggest that while there is consensus that science is about producing explanations, there are disagreements about how this is achieved and how it should be achieved. There is also evidence of disagreement regarding how these explanations are to be used particularly within technology. Over half the people questioned think that value judgements enter into all aspects of technology and that such value judgements should be discussed in all areas of the curriculum, not specifically in science and technology lessons.

The main findings which have arisen from the questionnaires are now presented in no particular order.
A SUMMARY OF THE MAIN FINDINGS FROM THE QUESTIONNAIRES

Science, by carrying out precise measurements is able to provide explanations or laws which are not fixed and immutable.

These explanations apply to only some aspects of human experience and scientific thinking is not seen to be different from other areas of human knowledge.

There is evidence that people believe scientists use an inductivist approach although some people think they actually use a variety of approaches.

No overall picture of the importance of instinct and imagination was obtained.

The majority of respondents do not believe scientists discover unchangeable facts and there is evidence of a little unease about the use of the terms 'fact' and 'proof'.

Few believe in the 'objectivity' of scientists considering that they are influenced by personal and political considerations.

Most people wish scientists to be concerned about the consequences of the work they carry out.

The public, scientists, engineers and academics should have more say in decision-making about how science and technology may be used.

Technology applies scientific knowledge to find solutions to human problems and to control the environment.

Over half the respondents thought that value judgements enter into all the processes of technology.

There was general agreement that value issues relating to technology should be discussed in all areas of the curriculum and not just in science and technology lessons.

Industry would be seen in a more realistic way if values were included and this may encourage more young people to work in industry.
8.2 The Interview Data

In Chapter 6 it was argued that interviews were an appropriate way of probing people's beliefs. The more open-ended and loosely structured the interview, the more likely one is to find out what interviewees think and feel. Research interviews are not however therapeutic or cathartic opportunities and hence they need to be focused. Such focusing was possible given that the questionnaire data was used to identify questions. Thus the findings summarised on above were translated into the following questions:

8.2.1 Questions to be Probed at Interview:
The following questions were used to structure the interviews but, given that interviewees were to be allowed free expression, the questions asked varied depending on interest of interviewees and time.

1. Beliefs about science

What is science?

Is science different from other areas of human thought?

If science is not thought to be different then why have a discipline called science?

If you think that scientists are influenced by politics, what is the effect of this influence?

Do you see any difference between questions 10 and 11, i.e. science concerned with discovering laws of the universe and science concerned with trying to explain observations about the universe?

What is the purpose of science?

What do you understand by the words truth, fact and proof?

What do you understand by instinct and intuition?
How important are instinct and intuition in science?

Do you see any differences between the people who should make decisions about genetic engineering and those who should make decisions about nuclear energy?

2. Beliefs about technology

What is technology?
In responding to the questionnaire some people thought that technology was applied science, others disagreed. What is technology other than applied science?

What is the purpose of technology?

Do you see any differences between technology and engineering?

3. Science and technology education

What are the differences, if any, between the technology carried out in school and the technology outside of school?

Do you use the words proof and facts in your teaching?

Do you discuss the role of instinct and intuition when teaching science and/or technology?

4. Values and science and technology education

Are value judgements only involved in technology when decisions are made regarding how the technological product is to be used?

Do you include discussion of value issues in your teaching?

5. Gender and science and technology

Why are there so few women in science and engineering?

Is there anything you wish to say about question 6? (Science is primarily a masculine activity)
8.2.2 Personal Details of Interviewees

Although these are given in full in Appendix 13, the following extracts are given here for convenience.

Figure 8.12

Sex of interviewees

<table>
<thead>
<tr>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>12</td>
<td>27</td>
</tr>
</tbody>
</table>

Figure 8.13

Area of work of interviewees

Figure 8.14

Interviewees working in Research

<table>
<thead>
<tr>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1</td>
<td>7</td>
</tr>
</tbody>
</table>

research
Figures 8.13 and 8.14 indicate a reasonably balanced range of interviewees was obtained; however this was not the case with reference to the gender of the research scientists and engineers.

(Code for interviewees

F = female  M = male  Phy = physics  Tech = technology
Bio/Biol = biology  T = teacher  Chem = chemistry  Eng = engineering
Res = research  Sci = science  Univ = university  Ind = industry
Primary  Home Econ = home economics

The number code refers to the interview transcript.)

Figure 8.15
Age of students taught

The full transcripts of three interviews are included in Appendix 14. This is just a sample, the other 24 transcripts are available for perusal.
The following sample comments are characteristic of the interviewees' responses.

8.2.3 Interviewee's Comments about Science
All the people interviewed thought that science is concerned with explaining and understanding what happens in the world. No one agreed that
"science is the only way to explain the world we experience"

One person commented:
"Science is part of everything we believe in" (7 F, Chem, T)
while another said science
is "asking questions about the meaning of it all - questions which have been previously left to theologians and philosophers". (11 M Phy, T)

Five of the twenty-seven interviewees (18.5%) thought that science was different from other areas of human knowledge and justified their belief with reference to the processes of science, citing precision, measuring, mathematics, and that science is typically "non-emotional" and "objective". Four people gave what might be termed an inductivist interpretation of the scientific process and one interviewee talked of constant hypothesising and predicting. Asked about the statement on the questionnaire regarding scientists trying to disprove their theories, two research scientists were adamant that this is what they did.

8.2.4 Objective and impersonal science?
I asked people to comment on the statement "Scientists are not really influenced by politics because they work in particular institutions and are pretty much isolated from society". It was said that scientists were influenced by political considerations in terms of the choice of research related to availability of funding. This influence might have been expected but the belief that the influence also affects the way the research is carried out and the findings from the research, was unexpected. People spoke of scientists having "vested interest". (4 M, Phy/Tech, T)
The comments from research scientists and engineers support the subjective nature of scientific investigation eg.

"Not to be left to scientists - we get too fanatical" (18,F,Chem,Eng,Res,T).
"Not many scientists step back from what they are doing sufficiently to see their work in context - sadly" (17,M,Tech,T).
"Experts are blinded in some way by being too close" (19,F,Sci/Tech,T).

The implication is that scientists are acting in a non-objective way for personal reasons to do with support for their research, with personal gain and to defend their own theories. Some interviewees referred to the cold fusion debate and research scientists gave personal or anecdotal accounts to substantiate their thinking. It was suggested that external influences on the whole process of science are increasing:

"This influence is recent and was less when laboratories were smaller" (1,F,Phys,T).
"Increasingly it coincides with financial reward" (15,F,Biol,T).

8.2.5 Facts, proof and science as truth

Only three interviewees thought that laws could be discovered which suggests that scientific 'truth' is not found but is devised or constructed. As a research engineer said,

"I do not regard scientific theory as fact because I think the existentialist concept of subjective truth applies in science too" (12,M,Phys,Eng,Res,T).

Many people interviewed were unclear about what is meant by 'facts' and some were uneasy about using the term. Two research scientists did not have difficulties with the term, one commented that "a fact is a truth" (M,Phy,Res) but he did not see facts as unchangeable. People expressed similar unease about the words 'proof' or 'proving'. 'Truth' was not mentioned by the interviewer but the word was used by two interviewees in relation to facts.

8.2.6 Instinct and intuition

All the interviewees believed instinct, intuition and imagination to be very important in scientific work. Research scientists were very definite about this.
8.2.7 The Teaching of Science.

Five of the six science educators working in higher education, considered the science now being taught in schools to be concerned with teaching and recalling knowledge with little emphasis on application of the knowledge

"[It is about] looking for right answers, the answers in the book" (4, M, Phy/Tech, T).

"[It is] pretty old, dogmatic science taught as if it is fact and taught by the teachers who think they know the facts" (8, M, Chem, Sci, Educator).

Practising science teachers in school reinforced this view:

"It is now more about teaching facts than investigative work" (22, F, Chem/Biol, T).

National Curriculum was seen as constraining and restrictive.

"Unless it is in the National Curriculum, we can't do it. Until this year we gave a balanced picture of science, now we are concerned with published exam results - the position is quite desperate" (22, F, Chem/Biol, T).

"With National Curriculum, science is seeming to be less about practical work, less doing, less first-hand for children. It is hard to make a lot of National Curriculum science relevant to children" (25, F, Biol, Primary, T).

Only one teacher in an independent school disagreed with the ideas expressed above and thought that there had been a regrettable move away from pure science in the last ten years.

The image of science presented in school is that it is concerned with facts and proof which are achieved by processes which are impersonal and value-free. The idea that scientists attempt to falsify theories or that imagination, intuition and instinct are important are not generally discussed. An alternative image is presented to some sixth-form students however, for example the role of instinct and intuition in scientific process is discussed. Teachers of sixth formers also said that the terms 'facts' and 'proof' should be used tentatively.
Asked whether they used the words 'fact' and 'proof' in their teaching, all the teachers interviewed said they did or supposed they did. Thirteen people seemed happy to use the terms, two people saying that pupils aged 12-16 were unable to understand uncertainties and 'shades of grey'. The two primary school teachers seemed happy to use the words 'fact' and 'proof', one encouraged pupils to find facts by carrying out observations or by looking in books. Four people, all of whom taught students over sixteen years of age, said they talked of the tentative nature of facts and proof.

"I will say there are facts but that we can't be certain what are facts and what are not facts" (19,F,Sci/Tech,T).

"I say you have to understand the limitations of what you are working with and that somebody else might come along later and disprove it or use it to improve on history" (15,F,Biol,T).

"I would use it [proof] providing one is cautious that one can never prove anything - you have to have that caveat" (11,M,Phy/Tech,T).

8.2.8 Interviewees' Views about Technology

On being asked to say what technology is, 19 people (70%) said immediately "it is applied science". I accept that the data may be skewed in that respondents may have felt compelled to answer in terms of science due to the format of the questionnaire; however the last two technology teachers I interviewed did not see the questionnaire before the interview and the first question they were asked was "What is technology?" They responded in terms of applied science.

Four interviewees said technology was more than applied science and two people noted that technology can exist without science and that technology has often preceded the science. Asked at interview about the differences between science and technology, six people replied that technology was concerned with profit, and selling.
Three categories of purpose can be deduced from the comments about technology. It is:

1. concerned with finding solutions to problems (from two interviewees);

2. about making things which can be sold (from 9 interviewees);

3. about producing a better future (from 13 interviewees). For example:
   "science and technology will give us a better world" (9,F,Phys,T)

and

"technology is about producing the wealth of the nation" (20,M,Phys,T).

Technology is perceived to be closely linked with engineering; four interviewees thought the two were the same and four thought they were similar but that there are distinctions. Reasons for the differences were not identified.

8.2.9 Technology Education in Schools

When asked about their aims when teaching technology, teachers gave various replies from developing pupils' awareness as consumers to the push for technology in the school from headteachers. All the technology teachers said National Curriculum technology was too complex and unworkable and thought that the rewriting of the Order was a good idea. Four science educators thought that National Curriculum technology had brought some benefits particularly in middle schools. No-one mentioned developing creativity in pupils and encouraging pupils to experience the satisfaction and enjoyment of making things.

Twenty four of the interviewees i.e. those linked with schools, spoke of the present confusion about technology education. The Engineering Council and others have expressed concern about the "Blue Peter" (a children's programme on BBC television) way of doing technology, i.e. using cardboard, glue and sellotape. One teacher made derogatory comments about such an approach saying this was not technology while another teacher said this was the type of technology carried out in her secondary school.
As asked about the differences between school technology and the technology which occurs outside of school e.g. industrial technologies, people mentioned differences in skill levels and in the resources available. Financial considerations were seen as the prime concern in industrial technology and whereas profit is not the main concern in school technology, it was seen as important. Technology in school was also defined as primarily design

"in a broad way from graphics to textiles" (1,F,Phys,T).

All the research scientists and engineers interviewed said they knew little about what was happening in school science and technology even though two had some responsibility for working with schools.

National Curriculum technology tried to bring together under the umbrella of technology, five areas of the curriculum. This does not seem to have happened. All the schools visited still had separate Craft, Design and Technology (CDT), Home Economics, Art and Business Studies departments, with Information Technology generally a whole school activity. In one school a teacher of Home Economics and a CDT teacher said they worked closely together and had been doing this before National Curriculum. In another school equipment was occasionally shared between the two departments.

Everyone interviewed believed that technology and science should work closely together in school.

"We should be blurring the edges" (4,M,Phy,Tech,T).

"It [technology] should be more science and maths and less textiles and home economics" (11,M,Phys,T).

Some people thought technology teachers should collaborate with all aspects of the curriculum:

"Most subjects link into technology" (17,M,Tech,T).

One teacher in a primary school had responsibility for the two areas.
In secondary schools science and technology teachers did not usually work together although in one school they borrowed equipment from each other. Two reasons were given for the lack of cooperation: a) the two departments were in different parts of the school, and b) personality differences. Having given one or both of these reasons, teachers often made comments about their colleagues which might be said to be derogatory or at least showed lack of respect for the teacher or the subject:

"You can't solve many technological problems without going through the scientific process" (4, M, Phys/Tech, T).

"I am antagonistic with technology, they pinch our equipment" (20, M, Phys, Sci, T).

"We do not communicate. Physics teach electricity and electronics but we usually have to teach it properly before we tackle electronics in technology" (27, M, Tech, T).

"When the science department does move from chalk and talk to problem solving activities it tends to be a sudden burst of potatoes and cocktail sticks. I am sceptical and cynical. I have been seriously into problem solving in the full meaning of the idea for a long, long time. To do it properly requires a whole change in pedagogy" (14, M, Tech, T).

Many teachers said the two departments were moving further apart following the introduction of National Curriculum and suggested reasons for this:

"Technology teachers are now saying we don't need the science teachers, our standing within the school is high and within the community is high. The scientists are still holding back because they are afraid of going down into the technical rooms where there is all this machinery and new technology" (17, M, Tech, T).

"There is mutual insecurity. There are few CDT departments that have the confidence to tackle the electronics - there is a feeling of inadequacy. There is
a perception by physics that CDT is trying to encroach. I have found it very difficult to get cooperation from physics. National Curriculum is forcing us further apart" (24,M,Tech,T).

"Before National Curriculum technology was taught by scientists and you were quite happy and then all of a sudden National Curriculum came in and said technology was a different subject and we just lost all contact" (7,F,Chem,T).

8.2.10 Interviewees' Responses to Questions about Values in Science and Technology Education

Three physics teachers noted that there was little opportunity to discuss value issues in physics:

"In a lot of physics 'A' level the subjects are pretty dry in terms of how they relate to human beings"(1,F,Phys,T).

All the physicists talked of nuclear energy as a topic. Asked whether value issues only enter into technology when decisions are made about how it is to be used, all interviewees believed that value judgements come into all aspects of the technological process and not just when considering outcomes.

"Value judgements come in when you decide you have to spend the money to create it in the first place or in a few cases whether it is desirable to create it" (2,M,Univ,Phys,Eng,Res,T).

"You probably are making value judgements when you are deciding what to do about certain things or whether to use certain bodies of knowledge" (3,M,Chem,Res,Ind/Educ).

"Value judgements come all the way through because you are planning all the way through"(4,M,Phys/Tech,T).

Although some interviewees said they did include value issues in their teaching and described examples of such, these were 'discussion of issues' rather than discussion of the values behind the issues. Examples given were
"New foods and the implications for communities and different cultures" (13,F,Home Econ,T).

and, from a primary teacher,

"last term we looked at human influence on the earth" (16,F,Biol/Sci,Primary T).

Asked specifically whether they discussed the values inherent in decision-making in all or some of the processes of technology, only three teachers said they did this. One technology teacher talked of economic values:

"Will the product sell? Is the choice of design, materials used and process employed, cost effective?" (27,M,Tech T).

This same teacher said that he thought the only values his pupils were interested in were concerned with profit. Two other teachers talked of durability of the product and its suitability for the task in hand. When I pointed out that the criteria they had described could be applied to a product such as a gun or knuckle-duster, all said they had never considered this possibility but said they realised this was an important point.

There are a number of possible ways of making explicit the value judgements in technology. One way is to encourage children to be explicit about the judgements they are making in their own technological activities. Asked about this a technology teacher said

"The whole process [technological projects in school] is based on their value judgements... in presenting ideas about what they will do or not do, they have to say in their folder why. A sophisticated child will say a lot of things at once, you would have to unpick it. We have too much to do to consciously attempt to address the wider social issues"(14,M,Tech,T).

This view was also expressed by another technology teacher.

Most teachers thought pupils were unable to consider and understand value judgements although a secondary school teacher said

"Yes some [ pupils ] are able to do this, 25% are good at doing this" (19,F,Sci/Tech,T),
and a primary teacher commented:

"You can make them understand the issues involved e.g. we have done this with pollution and the rainforests" (16,F,Bio/Sci,Primary T).

Attainment targets 1 and 4 [then included in the Statutory Order] were very relevant to value issues. AT 1 was concerned with identifying needs and opportunities for technological activities. All the technology teachers said projects which the children worked on were set by the teachers i.e. pupils were not involved in identifying needs.

AT 4 was concerned with the technology of other times and other cultures should be evaluated. No one said they were doing this, the emphasis was on the pupils' own work

"AT4 is not really what we are about"(14,M,Tech,T).

Evaluation of pupils' own work or of existing artefacts concentrated on:

"appearance, fitness for purpose, longevity, safety, suitability for intended age group, cost/performance ratio, whether it would be easy to market and advertise, sell"(11,M,Phys,T).

There was no evidence of discussion of value judgements behind these decisions e.g. why it is important that it should sell. Identifying human need as mentioned in AT1 appeared to be concerned with fitness of purpose, whether it would do the task in hand and whether it would sell. These criteria are not needs for technological activities but could be seen as opportunities for technological activities or rather opportunities to produce new products that will sell. This perception was tested as mentioned previously, by asking teachers what they thought would happen if children wanted to make guns or knuckle-dusters. As before it was clear that such an possibility had not been thought about. One teacher ignored the point by saying

"This is a girls' school and so it is unlikely to occur"(11,M,Phys,T).

and passed on to other things. Two said they would try to talk the pupils out of making such things and would finally insist if necessary.
All the research scientists or engineers said it was important to include discussion of value issues in science and technology education. One engineer involved part-time in promoting engineering in schools said:

"Value issues are frequently not an issue in a school context because they are only doing part of a technology and that part would not have negative issues. Most of what you teach children in science and technology is relatively value free" (2,M,Univ,Phys,Eng,Res,T).

Teachers spoke of the need to include value issues in terms of general educational aims such as:

"If they see a purpose for what they are learning they are more motivated; more and more children are wanting to know why" (11,M,Phys,T).

A number of reasons were given for not including value issues in science and technology, lack of time being one.

"Discussion in technology has to be there but at the moment it is just designing and making, there is not time for anything other"(17,M,Tech,T).

"If there was more time it would be a super thing to do [but] it is about trying to get through a syllabus or National Curriculum"(22,F,Biol.Chem,T).

"It tends to get tagged on at the end if there is time"(21,F,Chem,Sci,T).

Teachers' and pupils' lack of ability was mentioned.

"Value judgements are certainly at the back of my mind but when I come to try and get the children to describe why they make decisions, I really find it very difficult. Whether it is my failure or whether they have not reached that cognitive level or whatever, I don't know"(10,F,Phys,T).
"I don't think children are able [to look at value judgements being brought to bear in decision-making], their views are tainted by what they have read in magazines like Seventeen [a teenage magazine]. All the time we are asking children to make judgements based on practically no knowledge" (13,F,Home,Econ,T).

Discipline problems were also given as reason by one teacher:

"There are only some classes you can allow to go off beam, only the better behaved classes" (11,M,phys/tech,T).

These difficulties were not seen by an industrial scientist working in industry - education links.

"Teachers are pretty good at handling most of those [value issues and moral dilemmas]" (3,M,Chem,Res,Ind/Educ).

8.2.11 Pupils Raise the Issues.
Teachers pointed out that pupils often raised the issues e.g.

"We talk about recycling largely due to pressure from the pupils" (11,M,Phys/Tech,T).

"When social issues are discussed this comes from the children" (22,F,Chem/Biol,T).

Teachers said there was little time or opportunity to discuss these issues. I find this rather sad. Teachers may be suppressing and stifling pupils' interest and motivation. The strict adherence to National Curriculum seems to be a major reason for dismissing pupils' concerns.

8.2.12 The Use of SATIS Material
When asked about the inclusion of value issues one of the first people to be interviewed mentioned SATIS (Science and Technology in Society). This is a project managed under the auspices of the Association for Science Education, which produces photocopiable material for use in schools. As the name implies the aim is to place
science and technology matters in the wider context of society, nationally and globally. The material has been available since about 1988 and has been well received in schools. Although the material does not specifically address value issues or judgements, it was thought that the use of SATIS by a school or teacher may indicate a commitment to including the wider social issues. Understanding something of why and how it is used, or not used, may provide additional information about whether value issues are being included in schools. For this reason a question about the use of SATIS was sometimes included. Most people who were asked did not use it, but knew of it. It was used in a genuine way by three teachers to support the topic they were teaching but from the comments at interview, it seems that it is being used for reasons other than making explicit the issues in science and technology.

"We use SATIS in PSE [Personal and Social Education] rather than in physics" (9, F, Phys, T).

"Only as back-up or if teachers are away we will set work from it." (this said twice)

and


8.2.13 The Industrial Dimension

On being asked about the inclusion of value or social issues, teachers said sometimes they used industrial material to bring issues into the classroom.

"We use a video which touches on biotechnology issues but we do not discuss it because it is not on the syllabus" (22, F, Chem/Biol, T).

At the time of the interviews there was discussion within the department of Educational Studies at Surrey University, regarding the involvement of industrial companies in the production of Industrial Resource Material (IRM) which would address environmental issues. IRM is one of the means, if not the main way, that industry interacts with schools. I sometimes asked if they used IRM. An industrial scientist concerned with schools said:

"I think it [the image of industry] is improving, probably. We need to have
the whole area of wealth creation dealt with better in schools, you cannot discuss
industry except in the area of wealth creation and the use of wealth. Industry
has a self-interest in encouraging this, I also think it has a public duty" (3,M,Chem,Res,Ind/Educ).

A science educator thought that

"Industry is fairly ready to help schools when they can. Probably more could
be done in that area [ discussing value issues ] but few people are trained to do
it I suspect"(2,M,Univ,Phys,Eng,Res,T).

One teacher appeared to be wary of the motivation behind such material:

"We use material from various companies... industry. I say we have this
material because it is a form of advertising but I still use it. It is totally profit
related. Industry is not keen to open up the issues except to make the consumer
think they are ecofriendly"(20,M,Phys,Sci,T).

None of the IRM I have seen makes explicit the value judgements involved in decision-
making.

8.2.14 Gender Aspects

Asked why there are so few women in science and engineering, people talked of
differences but not intellectual abilities. It is interesting to note that the male technology
teachers thought that girls are just as capable as boys:

"in fact more so in some areas. Their design element is superb, they look at
things more closely" (17,M,Tech,T).

At interview one woman commented on differences in visual-spatial ability from her
reading and some people said boys are more interested in mechanics than are girls and
that this was due to innate differences. People spoke of masculine and feminine things
e.g. cars and dolls.
Many commented that women value, and are more conscious of, relationships. Women were also said to be more caring and helpful and generally interested in people and not things. This has consequences:

"If you market engineering and science as things to do with weird equations and power stations then you are not attracting the women. But if you were to sell it as the production of electricity which is of use to the human race then I think we would change it" (4, M, Phys, /Tech, T).

Men were thought to be more aggressive and competitive but it is not said why this is important for technology although there seemed to be an assumption that it is.

"We have done everything possible [to encourage girls] but at the end of the day it is the aggressive side of the boys' nature which on rare occasions is also in girls...We do not want to make the girls feel different. They are not different, they have just as much capability as a boy" (17, M, Tech, T).

"It is good for a boy to be successful and aggressive in order to get that success. The opposite is true of girls, if women are successful it is normally because they have been aggressive in some way or been assertive in some way which is not a female quality and therefore they are not looked on quite as admirably by the majority of society" (15, F, Biol, T).

Differences in confidence were discussed:

"Boys are more show off" (sic) (21, F, chem, sci, T).

"If the boys do not understand they will stand up and bluff their way through it. Girls won't do that. Boys probably gain because they want to outshine the girls, bravado, make themselves heard. If they are not being heard they will make sure somebody does hear them. Girls will not react in that way" (15, F, Biol, T).
"The girls also tend to give way to the boys. They will defer to them" (16,F,Primary,Biol,T).

Society's expectations of women were discussed:

"It is seen as not female to be mathematically intelligent" (15,F,Biol,T), and

"Men [are expected] to go out and earn a crust and go out and earn a bigger crust" (4,M,Phys/Tech,T).

"Girls who are good are dissuaded from going into engineering" (9,F,Phys,T).

There was a mixed response to the statement "men have influenced the way science is done so that it is primarily a masculine activity": one man and five women agreed.

"I definitely think science and the way it is carried out and its images are very, very influenced. It is fundamentally influenced by the dominance of men within science through history: from what labs look like to its status as something which appears to be something which is fairly powerful and high status and objective. And I suppose often it's seen as having masculine qualities because it's been men that have been influencing it. The whole feel of what science is about I think has a masculine image to it - particularly the physical sciences" (1,F,Phys,T).

"I think it is part of the nature of science that it has got to be exact and measure things. That is probably a more masculine characteristic and it is not that men have made it like that, it is a feature of science" (19,F,Sci/Tech,T).

People suggested the masculine influence was present in areas other than science, for:

"Men historically have been in the positions of power" (4,M,Phys/Tech,T).

Three people pointed out that women had made contributions but these had not been recognised. Their evidence is that the way women have been socialised explains why there are fewer women in science and technology. Unlike the questionnaire data, which
showed no difference in response, more women interviewees thought that science was masculine.

8.3 Summary
Mindful of the need to concentrate on the main issues which arise from the research data, I identify these to be:

1. Beliefs about science, the teaching of science and the differences between the personal beliefs of educators and the way they teach about science.

2. Confusion about the nature of technology and the remit of technology education.

3. The apparent lack of valuing in technology education.

4. The influence of gender on science and technology issues.

These will be discussed in the next chapter.
9 DISCUSSION OF THE FINDINGS

9.0 Introduction
Having identified the main findings, in this Chapter I shall first link these with published literature and so attempt to draw out emerging theory. Later I will begin to consider the implications of the emerging theory for changing the way technology is taught, although this will focus on schools, I believe the findings have relevance for other educational institutions.

9.1 Beliefs about Science
The data shows general agreement that science is concerned with observing and explaining the world. However there is some evidence of two contradictory responses, namely:

i) that science is straying into areas where it has no jurisdiction;

ii) that science is part of everything in which we believe.

The first response relates to the questionnaire statement "Given sufficient time science will be able to explain all known phenomena." The majority of people disagree with this statement and do not see that science is competent for dealing with all matters. Scientific explanations or facts are not seen as fixed or immutable but as context and time dependent.

The second response indicates that for a few people, science is the only legitimate method for explaining phenomena: Ratzsch feels that people are "seriously confused" (1986:99). While accepting Ratzsch's belief, I think people intermingle frameworks of interpretation when seeking explanations. Polkinghorne (1988, 1992) for example, uses physical science concepts in religious discussions to explain divine creation and maintenance of the universe. He seems to imply that science has a role to play in interpreting religious experience and in 'meaning of life' questions. In doing this he seems to want religious belief or conviction to be capable of being explicable using a
'scientific' framework. I find this interesting recalling the discussion on positivism (see sections 3.10 and 3.1) and the fact that religious experience and explanations are excluded from science. Religious belief is central to Polkinghorne's experience, so is a belief in science as a way of explaining experience, hence he apparently must bring the two together. This approach is, presumably, credible to his peers who hold both belief systems and hence it can be said that physical science explanations of creation are justifiable for they are objective in terms of sharing ideas.

This raises for me the possibility that people try to use scientific explanations in areas where it is not appropriate. Many respondents thought that scientific explanations have to be restricted to appropriate phenomena, yet I wonder whether people believe that science cannot explain everything, or say they believe this, while still trying to find scientific explanations. This raises for me, the ideas of intermingling frameworks of interpretation or belief systems, and the concept of science as the superior means of explanation. Respondents who thought that science was different from other areas of knowledge spoke of its precision, measuring, objectivity and non-emotional nature. Yet scientists are seen to work in ways which can only be described as subjective: their feelings and motivations are seen to influence the scientific process and the findings. This picture was verified by the practising research scientists.

This raises a query regarding the understanding and use of the 'objective'. If people define objectivity as 'putting explanations into the wider arena for testing by quantitative means, then there is no tension. Scientists can, and according to Polanyi (1958) do, work in ways which involve tacit knowing, intuition and passionate commitment; but by placing their theories into the wide arena for testing - so that according to Popper, the theories can be refuted - the knowledge becomes objective. Scientific theories should thus 'stand on their own feet'. Evidence, rational argument and testing are crucial, although testing is not necessarily conclusive. Theories, evidence and testing are shared in credible scientific papers which are produced in clear, coherent and consistent ways which enable others to replicate the findings. The point is that the framework of interpretation, the means of testing and evaluating has to be clear. This is illustrated by
the concepts of experimental quantitative methods and interpretative, qualitative methods as discussed at the start of Chapter 6.

The view of objectivity whereby ideas are placed into a wide arena, accords with the wish of respondents to have more people, e.g. the public and academics, involved in decision-making in addition to industrialists and politicians. What seems to be meant by objectivity is that theories (and decisions) are tested but these are not discovered but constructed by scientists. Social constructionist thinking (see section 3.14) is not at odds with this understanding of objectivity. It is not the testing which is at the centre of the debate but the process by which the theories and evidence are produced.

Accepting objectivity as testing by others is not inconsistent with the view that the processes of science are value-laden. It is interesting to note that in addressing objectivity, Popper (1959) argues that he is concerned with logic, methods and procedures, not with psychology. Such a view is acceptable if the contribution of instinct, imagination and intuition are still acknowledged. The problem seems to me to be that in observing and describing the processes of science only in terms of logic and methods, the 'personal' elements may be ignored. The ramifications of this are that while the scientific establishment confines itself to seeing only rational, logical ways of working and knowing, and prides itself on being impersonal, there is no remit to address the personal, psychological and social influences, what Kuhn (1962) identifies as 'the body of belief' shared by the scientific community (see section 3.11). More importantly, adherence to the rational, logical hinders reflection on the two way relationship between science and society.

The differences in respondents' perceptions about science reflect the continuing discussion between philosophers, sociologists and historians of science about the nature, methodology and purpose of science (Chapter 3). This discussion can be depicted as a polarisation between the 'weak' concept of objectivity, (Polanyi 1958, Kuhn 1962, Harding 1986 and the 'hard' concept of Ayer (1963) and other positivists.

At the end of Chapter 3. I rejected positivistic views of science favouring a social
constructionist one. Indeed the research methodology of this thesis is underpinned by such an approach for it is primarily about eliciting and valuing people's interpretations.

9.2 The Science in Science Education

The data indicates that educators do not see science as discovering the truth, or proving immutable facts, and that they hold social constructionist views. However the same people said science in the classroom is increasingly about transmission of facts as if they are proven. The image of science presented is of facts proved by procedures which are impersonal and value-free. The idea that scientists attempt to falsify theories or that imagination, intuition and instinct is important are rarely discussed. In a recent personal conversation with two research scientists, a nuclear physicist and a biochemist, I was told of undergraduates' inability to trust their intuition and instinct; to follow a hunch. They asked what was happening in schools to stifle this.

The difference between educators' personal beliefs, which can be described as social constructionist, and the science they present to students which is reminiscent of positivism, is, I think, the most interesting and potentially important finding from the research. Before examining possible reasons for this I feel it is necessary to recall the problems of exploring beliefs.

Beliefs are hidden assumptions and are not truly rational involving volition, emotions and feelings (see section 1.9). If, in the terms of Personal Construct Psychology, they are seen as core and peripheral constructs (see section 1.11), then probing core beliefs will be not only problematic for the researcher but uncomfortable and threatening for the believer. Beliefs are often not articulated because individuals are not clear about what they believe or about the frameworks of meaning they are using. As noted in the Introduction to this thesis I had never examined my understanding of science and technology although and I had been working in science for nearly thirty years, fifteen of which were as a teacher of science.

Recalling that much behaviour is a consequence of habit rather than the influence of beliefs or values, the problem may be explained but is, at the same time compounded.
This may account for discrepancies between stated beliefs and behaviour e.g. when people say that scientific explanations are only useful for some phenomena yet such explanations are brought to bear in inappropriate situations.

9.3 Why are Educators Presenting a Different View of the Nature of Science from the One they Hold?

The value-free, impersonal picture of science presented contrasts with educators' personal beliefs about the nature of science. Personal beliefs about the nature of science are characteristic of the critical thinking of post-modernistic society:

...emphasis in modernity [is] on a particular way in which human beings should relate to the world. In the early modern thinkers such as Descartes and Hobbes, one sees this relation beginning to emerge clearly. The individual subject is conceived of as an isolated mind and will; and his vocation is to get clear about the world, to bring it under the control of reason and thus make it available for human projects. The modern world, says Derrida, stands under the imperative of giving a rational account of everything; or, as Foucault more ominously puts it, of interrogating everything. (White, 1991:2-3)

This interrogation is manifest in art, architecture, literature, philosophy, society, the media and politics, in the writings of philosophers of science such as Feyerabend (1981) and Lakatos (1976). White (1991) sees the consequences of this to be the growing incredulity toward traditional metanarratives, and the emergence of new social movements such as the Green movement and Feminism. Winner (1993) relates this to decision-making about technology, when he speaks of the "absence of widely shared understandings, reasons, and perspectives, that might guide societies as they confront the powers offered by new machines, techniques, and large-scale technological systems" (in Winkler and Coombs, 1993:46).

The issue for me is not that most of the educators in the sample hold 'post modernistic' and social constructionist views of science (it would be more surprising if they did not), but that in their teaching the image of science they appear to endorse is what might be termed 'modernistic'. By this I mean logic, rationalism and determinism are
emphasised and the human interventions in the scientific process are ignored. Students are not helped to see that science is only one way of thinking about experience (National Curriculum Science, 1989), or that scientific explanations change in the light of new knowledge.

The educators in the sample are presenting science reminiscent of positivism which is characterised by:

... its incorporation of mathematics and its development of a powerful logical technique. It is thus able, in regard to certain problems, to achieve definite answers. (Russell, 1946: 788)

Later in this quote however, Russell says:

There remains a vast field... where scientific methods are inadequate. This field includes ultimate questions of value; science alone, for example, cannot prove that it is bad to enjoy the infliction of cruelty. Whatever can be known, can be known by means of science; but things which are legitimately matters of feeling lie outside its province.

The points to note are certain problems, and scientific methods are inadequate [for] questions of value. These qualificatory points are not being discussed in school science.

Holding a belief which is at odds with what one does is a source of tension and a conflict of values. I think that educators and research scientists are experiencing a conflict as indicated by the number of people who said they felt uncomfortable when asked about facts and proof.

Although respondents talked about the need to motivate pupils, and it was thought that this could be done by pointing out the relevance of science to everyday life, teaching science as immutable, value-free, impersonal knowledge hinders if not prevents this. It is not surprising that science is taught this way for, as Brew (1991:27) notes, value-freedom is highly esteemed and in science, values, morals, feelings, desires and interests are viewed as irrelevant. Moral judgements and emotional factors play no part
in traditional scientific method, and, "in training young scientists we teach them to ignore their moral scruples". Rogers is clear however that this is not a tenable position because:

In any scientific endeavour - whether "pure" or applied science - there is a prior personal subjective choice of the purpose or value which that scientific work is perceived as serving... Any scientific endeavour, pure or applied, is carried on in the pursuit of a purpose or value which is subjectively chosen by persons. It is important that the choice be made explicit, since the particular value which is being sought can never be tested or evaluated, confirmed or denied by the scientific endeavour to which it gives birth and meaning. (Rogers, 1982: 391-395)

Teacher as authority (see section 4.2) concentrating on handing over, or delivering knowledge, is commensurate with the value-free image of science, as described by Brew. Upholding the value-free image enables the teacher to pretend he or she is being objective and neutral. There is no remit to include the human dimension in science and the subjective elements.

In educational circles it is now common to hear people speak of 'delivering' the curriculum. The implication is that what is to be learned can be delivered or handed over to the learner. This is incommensurate with including wider issues, social outcomes and ethical dilemmas and with liberal, academic approaches to education where critical reflection and evaluation are valued. At the extreme this is illustrative of an ideological approach which sees schools as places where the young are indoctrinated into particular ideological positions, perhaps the ideology - 'technicism'. (see section 2.5) The delivery model is one which fits well with seeing knowledge as value-free and transmitting facts.

A delivery model of education also fits with the traditional rationale of science. The scientific establishment operates by promoting agreement and sidelining controversy (Kuhn,1962), peer review upholds conformity (Polanyi,1958) and scientific papers misrepresent the scientific process (Medawar, 1979). Concentrating scientific approval
in the hands of an elite group - the scientific establishment - reinforces and perpetuates the high status of pure science (see section 3.8). One consequence of this is that:

science in context of use ... [has been] accorded secondary and dependent status, signified by the term 'applied science'. Correlatively, organizations of scientific knowledge reflective of utilitarian interests were downgraded in educational terms. (Layton et al, 1993:9)

The science teacher might, therefore, teach science as value-free in order to maintain the high status of the subject. The perception of science as high status is reflected in a recent book which has stimulated acrimonious discussion. Appleyard (1992) hypothesises that the major belief system in society today is the rationalistic, reductionist, impersonal scientific one. Value-free knowledge is something people can believe and have faith in for it provides answers which are independent of human foibles and interests. Believing that science can explain most phenomena, or pretending that it can, is, according to Appleyard, a widespread belief. Nor is this unforeseen for it provides some sense of comfort in a world of controversy and uncertainty.

Head (1985) looked at personality characteristics of adolescent boys and girls and how these link with choosing or not choosing science subjects. Boys who had cut and dried views on many matters, chose science by foreclosure making commitments without thorough thought. He noted that this approach was likely to be accompanied by rigidity in thinking. Adolescents who uncritically adopt the concepts, perspectives and values of others are comfortable with science when it is taught in a value-free way. It makes little emotional demand and appears to offer clear, precise answers to problems. Head believes that this accounts for the 'rigid, authoritarian attitudes often associated with scientists' (cited in Kelly, 1987:19).

If Head is right, and it reiterates what Brew (1991) says, there is a particular problem in science education and by inference, in technology education. Science teachers, particularly male teachers, are likely to want to stay well away from the inclusion of values in their teaching, and indeed have chosen science for the very reason that it does not include such subjective elements. I suggest that rigid, authoritarian attitudes are
translated into teaching styles and strategies that allow teachers to retain authority and control. They have the 'knowledge' which they can deliver to the learners.

This need for clear, precise answers is an illustration of a need for certainties. Alongside the dissatisfaction with traditional metanarratives (White, 1991), people still search for certainties as Descartes did (Anscombe and Geach, 1972: 45-57). This search may be seen in the increase of fundamentalism, not only religious fundamentalism, but also in politics and education as is evidenced by the call to return to basic truths and core principles and values. This human need for certainties is outlined in Kohlberg (1984) on moral thinking, Perry (1970) on student development, Fowler (1981) on moral and faith development and Hull (1985) on cognitive dissonance. It seems that many people want clear guidelines and rules for decision-making, and linked to this, have a need for faith and trust in something (section 1.10).

Explaining why they presented science as proven facts, some teachers spoke of pupils' need for clear answers and their inability to accept uncertainties. There is no consensus about the age at which students are expected to be able to deal with uncertainties. One primary teacher thought that pupils could understand the issues, some respondents thought it was alright to discuss issues with sixth form students and during a recent conversation with a university biochemist, he said that students were only able to address such issues at post-graduate science level. Rather than concentrating on the 'right' age, I believe that research into the existence of education for addressing uncertainties will be more fruitful.

Teachers also blamed the National Curriculum for having to transmit facts. This is no doubt due to the requirement to assess, and provide evidence of assessment, the statements in various attainment targets along with the requirement to publish the results. Whether the National Curriculum is actually about delivering facts or whether this is how teachers perceive it and it is actually being misinterpreted, is not clear. It should be noted however, that there is evidence to suggest that teachers may not be misinterpreting the National Curriculum Orders when they see the priority to be the transmission of facts (Black, 1992, Bowe et al, 1992, Graham and Tytler, 1993).

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Actually what is at issue here is not so much that facts are taught but how this is done e.g. whether the facts are related to experience and whether the origin of the facts is discussed. (It will be interesting to see if more investigative, contextual science is taught if and when the new Science proposal (SCAA, 1994b), with the reduced number of statements, is introduced.)

9.4 Beliefs about Technology and the Teaching of Technology

In Chapter 2 it was noted that the public usually sees technology as applied science. This might be expected for:

Many, particularly those outside the scientific community, think that the first priority of science should be the development of applications which will "deliver the goods" in a concrete sense. (Cobb et al, 1991:23)

This view of technology was prevalent in the data. Most people referred to technology as applied science. Some interviewees were keen to distinguish between science and technology speaking of technology as: related to selling and profit, finding solutions to human problems, producing a better future and controlling the environment. If it were possible to obtain consensus about the major human problems of today, I suggest these would be related to crime, unemployment and poverty with environmental damage would be high on the list. The data indicates that few respondents think that technology can help with such problems as crime, unemployment and poverty or that it will solve current environmental problems. I am left asking therefore "Which problems can technology help to solve?" and concomitantly "How will we know that technology has solved them?"

This confusion about the aims and purposes of technology, is reminiscent of the variety of definitions of technology proffered in Chapter 2 and is reflected in respondents’ understandings of the aims for technology education. Any consensus about aims appears to centre around economic factors, indicated by comments about producing profit and encouraging pupils to be more aware as consumers. This is not unexpected given the statements from Government ministers and bodies such as the Engineering Council (Smithers and Robinson, 1992). What I find particularly sad is that nobody in the
sample spoke of promoting creativity in students but I think this may be a consequence of linking technology with science rather than with design.

It is difficult however to separate beliefs about science from beliefs about technology. A White Paper on science and technology (1993) promoted the establishment of panels of experts from each technology sector in the economy, in the anticipation that wealth creation and the needs of the economy will be promoted (Patel, 1993, THES 21.5.93). Commenting on this White Paper, Thompson writes "It [the paper] will certainly be welcomed by science teachers for it reaffirms the importance of the subject in creating future prosperity for all" (1993, TES 4.6.93). The view that science and technology underpin the nation's wealth creating ability is widespread and is behind the push for more technology education (see section 2.2). It is linked with a root paradigm in Britain which is related to economic competition, market forces and the market economy.

As noted earlier defining technology as applied science can enhance its status. At the same time however, science is valued because of the achievements of technology (see section 2.1). If the main aim for technology is producing marketable goods then the traditional, pure, 'elitist', high status image of science which separates facts from values will provide an interpretative framework which will not clutter economic goals with human contexts. This is the Baconian notion of man as lord and master of creation, who, because he understands nature, is able to use it for utilitarian purposes. Such a view is evident in the survey responses, but should be compared with the thinking of some present day biologists (Lovelock, 1979; Sheldrake, 1987), theologians (Fox, 1988; Radford Reuther, 1992) and feminists (Griffin, 1978; Merchant, 1980) who believe that rational, mechanistic, reductionist science has led to the exploitation of the natural world and the alienation of human beings from nature.

I see a dilemma here. Technology as applied science cannot adopt wholeheartedly the traditional scientific culture typified by pure, fundamental research which excludes possible applications of the acquired knowledge because

...technology is always purposeful (i.e. developed in response to perceived needs
or opportunities, as opposed to being undertaken for its own sake), takes place within a context of specific constraints (e.g. deadlines, cash limits, ergonomic and environmental requirements as opposed to unconstrained, blue-sky research) and depends on value judgements at almost every stage. (NCC, 1988:4)

Respondents would presumably agree with this statement; technology is seen as value-laden in all aspects of the technological process. In striving to achieve an outcome or purpose, technology must be holistic. The technologist draws on scientific knowledge, but the whole is greater than the parts. The purpose or end vision is always the priority and reductionist approaches are useful only for problem identification and solution and for promoting economic efficiency as in production lines.

Scientific knowledge is certainly an essential component of technology and hence of technology education: the knowledge is to be used and applied in the service of a development. Given that epistemological considerations are rarely addressed in science education, it can be assumed that this is the case in technology education.

Polanyi wrote of the technologist needing to keep in mind a 'whole panorama of advantages and disadvantages'. This for him illustrated the 'conflict of values which makes it difficult to mix the two occupations' [scientists and technologist] and of the 'sharp division between science and technology' (1958:178). Technology has to be distinguished and distanced from the kind of science education which inculcates such a 'hard' view of science and which decontextualises knowledge. The problem is that along with the scientific knowledge may come, albeit unconsciously, the framework of meaning which values decontextualisation, and this is at odds with a technology which is inextricably context dependent, concerned with human activities and with valuing. Technology educators need to ask themselves whether they are importing the means of seeing and explaining which is typified by the 'hard' view of science. One way to do this may be to think of Design and of Technology (see section 9.7).

The inter-relationship between science and technology is evident, but hard to describe (Chapter 2). The debate continues in the literature and at conferences. This is not only
of academic interest, it is problematic for relationships between science and technology departments in schools especially since the publication of the first Science and Technology National Curriculum Orders. Teachers think the two departments should work closely together even though this is not happening. Reasons for collaboration were not offered but, if technology is thought to be applied science, perhaps the reasons are thought to be obvious. It is important that the relationship is worked out so that collaboration is fostered and students are not disadvantaged. At a different level it is important to see whether there is a shared epistemology and framework of meaning and if there is, what the consequences of this are.

Layton (1993) believes that technology more than any other subject, challenges the historic role of schools as institutions which decontextualise knowledge. This statement is taken from his book entitled 'Technology's Challenge to Science Education'. Borrowing the idea, and paraphrasing, the questions to ask might be "What is the influence of science education on technology?" "What is the epistemology of technology?" There is currently an assumption that in education, we should be concentrating on basics and not waste time indulging in academic, progressive, left-wing debates. It is fashionable to denigrate philosophical reflection. An example of this is Smithers (1992) in his keynote address explaining that the Engineering Council appointed Robinson and himself to write the report (Smithers and Robinson, 1992) because the previous report had been "philosophical waffle" and not what was wanted.

I am reminded of the discussion on assumptions about shared perspectives and values in the first chapter typified by the Carey quote (section 1.7) and the group beliefs and values (section 1.9) Actions are justified by recourse to apparently collective beliefs and values "we all think". Actions are also justified retrospectively. This research indicates that there is a lack of consensus in technology education, and assumptions about its purpose remain unchallenged. I believe that undertaking widespread discussion about the philosophical basis of technology and technology education is a priority.
9.5 The Teaching of Science and Technology and the Exclusion of Values

The main aim of the research was to investigate awareness of values in decision making in technology. In the schools surveyed and according to the perceptions of those indirectly concerned with teacher education, the only values being included are economic values concerned with questions about fitting the intended purpose, durability, cost-effectiveness and sale potential. These are values which are internal to technology i.e. efficiency and effectiveness (see sections 2.1 and 2.4). Terms such as effective and efficient are not value-free as indicated by questions such as: "Effective for what?" "How is efficient identified?" Borgmann (1984) postulates that the purpose of technology in today’s Western culture is to produce goods which are easy to use and thus people become merely consumers of technology. This purpose fits with the internal values of technology. Borgmann believes that critical evaluation is not to be restricted to the framework of technology typified by efficiency and effectiveness. It is clear that if the framework is restricted then it is permissible to examine only certain values namely those which fit within the technology framework. External values such as aesthetic, social, moral and spiritual values lie outside this framework.

Developing students’ critical evaluation of a range of values is part and parcel of good technology education:

Any subject which involves the processes of making judgements, decision-making and optimising, needs by its very nature to be recognised as being value-centred, rather than this being denied or underplayed. Quality designing and making, resulting in quality products, will not take place without such processes being made explicit to the activity. Young people will need to be taught to recognise, address, acquire and develop such process skills, and to become increasingly discerning about when and how to apply them. (Farrell, 1993, 53)

What is not defined in this quotation, and is essential to the debate is the meaning of ‘quality’. The draft proposals for a revised National Curriculum Technology Order offer suggestions for exploring quality in the knowledge and understanding sections of the programme of study (School Curriculum and Assessment Authority (SCAA), 1994a:10,17,21). Summarising these, quality has been achieved if the product or
application meets a clear need, is fit for its purpose, is an appropriate use of resources and meets manufacturing and maintenance requirements. It is also to be judged according to its impact on the environment.

This proposed Order potentially provides opportunities for discussion of a wide range of value judgements by suggesting that a quality product can be assessed by criteria other than how well it is made and whether it will sell. Recalling teachers' perceptions of National Curriculum (section 9.3), it is worth noting the order in which the sections of the programme of study are presented. First designing skills and making skills, then knowledge and understanding followed by activities to develop capability (SCAAa, 1994). Quality is point five of the knowledge and understanding component. Point four of this same section 'products and applications', includes looking at intended purpose and the views of users and manufacturers. It is unfortunate that only after defining the skills and knowledge is the purpose for their acquisition addressed. One is led to ask what message teachers will take from this Order. Is it that skills and knowledge are all important and the reason for activity less so?

Within this document the image of need and the reason for the technological developments relate to satisfying consumer demand. Although not clearly stated it would be more accurate to say some needs of some consumers acknowledging that some people's needs are met, that some gain, but often this is at the expense of others, the losers.

Within UK society, consumer satisfaction now refers not only to the purchase of artefacts but to the purchase of educational and health care services. Quality is equated with consumer satisfaction and is part of a belief system which prizes the market economy. Inherent in this is the provision of a product or system which can be assessed in monetary terms and can be sold. Such a system has 'internal values' (just as technology does) which may also be summarised as value for money, cost effectiveness and using resources efficiently. Taking a step further to look at the beliefs behind the trust in market forces, one could suggest materialism and trusting in possessions and money; it should be noted however that there is increasing concern and publication.
about the morality of the market place.

If quality is about consumer satisfaction and cost effectiveness then it is not surprising that technology should be primarily about producing marketable goods. The repercussions of interpreting quality in this way is that, as noted earlier, the values to be considered are inevitably limited to those related to efficiency and effectiveness, wealth creation and the ability to exert power over others. If customer satisfaction is all that matters then, eugenics programmes using bioengineering or genocide using advanced weapons are acceptable and if a despot is satisfied with the chemical weapons which are sold to him, that is all that matters.

Limiting the values which might be addressed to internal ones is acceptable and justifiable given current emphasis on market forces. Doing this and presenting technology as value-free, also means that the technologist, the educator and the student do not have their beliefs challenged. The educator remains safe and avoids taking risks by limiting or ignoring the external aesthetic, social, moral and spiritual values. This concept is important to the emerging theory of this thesis.

The data indicates that even though educators may acknowledge that external values are inherent in all aspects of technology, these are not considered in the teaching. This is a somewhat parallel situation to that of science educators. There is a mismatch between the personal beliefs and the beliefs being taught. Referring to Pacey’s culture of technology model (1983:6) a ‘restricted meaning’ of technology is being taught while the teachers hold a more ‘general meaning’. For me, Borgmann’s (1984) framework of technology and Pacey’s ‘restricted meaning’ of technology are reminiscent of the hard, functionalist, scientific framework of interpretation which emphasises the technoscience principles and so exclude the human aspects. Ellul (1965) commented that whatever the context of the technology the rational mechanistic process is brought to bear even on the spontaneous or irrational. Feminist literature can help in raising awareness of this dichotomy and needs to be read and discussed far more widely than it currently is by technology educators (see section 9.6).
It is useful at this point to revisit the reasons I offered for this mismatch in science educators' beliefs (see section 9.3) and consider whether they are applicable to technology educators. I believe the following reasons are transferable:

1. Moral judgements and emotional factors have traditionally played no part in technology education.
2. ‘Delivering’ the curriculum is a perspective which applies across subject areas.
3. Including values requires different teaching and learning methods than those traditionally used in the delivery model.
4. Technology has traditionally been a masculine subject. According to Head (1985), males choosing technology may have cut and dried views, be rigid in their thinking and relate to technology because it does not involve feelings.

In addition to these must be added some of the points discussed in this section which refer particularly to technology:

5. There is confusion about the aims and purposes of technology which is reflected in technology education.
6. There is confusion about the relationship between design and technology typified by the terms Art and Design and Design and Technology.
7. Technology is seen to be closely linked with improving the economy of the country and with marketing products.
8. Technology is closely related to science yet is different but the differences are not clear.

The beliefs of educators and the relationship of these to educational practice (points 1-4) are the main issue in this thesis. The last four points are important also and will be carried into the ensuing discussion.

9.6 Beliefs about Gender
No-one in the sample thought there were relevant intellectual differences between the sexes but it was noted that women were interested in, and valued human relationships more than did men. Different characteristic and behavioural patterns were described
which corresponded, not surprisingly, with societal expectations. Masculinity is associated with independence, self-reliance, strength and leadership. Femininity is associated with conformity, passivity, nurturing and concern for people (A. Kelly, 1987). Interviewees said that males were more confident, aggressive and assertive and by implication these characteristics are particularly valued for they correlate with the perception that technology is about selling and making a profit and competitiveness. On the other hand the belief that technology is about solving human problems and producing a better future implies a need for greater consciousness of relationships.

Women value and are more conscious of human relationships; are more caring, helpful and interested in people and not things and their perspective is essential for valuing in technology. At interview, one man of the 15 interviewed and five of the 12 women interviewed, said men have influenced the way science is done so that it is primarily a masculine activity. Applying the masculine, hard science framework is not useful for:

Conventional science is strongly masculine in its orientation, reflecting traditional stereotypical male values: it is 'hardnosed', objective, value-free; it eschews the ambiguous, the speculative, the vague, the beautiful and the good. (Mitroff and Kilmann, 1978)

Hynes (1990) Fox Keller (1985), Alic (1990) Intermediate Technology (1994) present insights into ways of ‘rethinking’ the history of technology and ways of respecting women’s past and present contributions. Writers such as Franklin (1985, 1990) challenge the scientific and technological establishments and educators to present a realistic and relevant view of science and technology by taking account of women’s ways of working.

On a more practical note, if quality is seen as customer satisfaction: Do male consumers look for different factors when evaluating a technology product than do female consumers? If this is the case what then are the consequences for assessing the work of males and females?
9.7 Design

Except for noting that girls are often more skilled at design than are boys, none of the interviewees spoke of developing creativity or the skills associated with design (see section 2.3 for a brief discussion of design). This may be a consequence of the sampling method which linked science with technology, it may also be due to confusion about the nature of design and its role in technology education.

Garner (1992) refers to the complexities of professional design practices which are mirrored in the school situation when one tries to delineate design, technology or design and technology. Smithers and Robinson (1994) found that art and design was offered within the remit of technology in 51.6% of the 349 schools sampled. (CDT was offered in 99.7% and home economics in 94.3%) In the list of recommendations from this same report is the following:

... work progressively towards adopting the simpler label ‘technology’ for what is now called design and technology since technology implies design in the way that science implies investigations. (1994:19)

Although the request is logical, it is unfortunate for the importance of design may be overlooked or marginalised. Design necessarily involves human beings, ‘all designing must have a recipient’ (Kimbell, 1993:9). It is the area of technology in which it is most obvious that value judgements are being made.

Design is linked with defining quality of life, with asking what are the trade-offs and using non-financial matters as criteria when making value-judgements. (Mackenzie, 1994)

In Art and Design there is no problem about including values. The problem is bringing in the technology. Designing is about making individual and group judgements. (Billett and Perkins, 1994)

Failing to investigate respondents’ understandings of the design process has been an omission in this research. This has probably arisen due to my bias and past experience.
Steeped in science, I did not understand or appreciate the nature and importance of design. Now after further reading and discussion, I argue that design must be given a prominent role. Smithers and Robinson (1994) may be right when they say that technology necessarily involves design but it is important to keep design in people's minds.

Separating Art and Design from Technology is part of the confusion about technology education. A way of facilitating cooperation while upholding and valuing the varied experience and skills of all technology teachers has to be found. A starting point could be establishments of teacher education which have separate departments of science and technology and of art and design and where there is little or no collaboration. Seeing design and technology as a continuum where the position on the continuum depends on the technological activity may be a way to facilitate collaboration.

While regretting the omission of design in my research, this is itself an illustration of the major finding of this thesis, namely the need to examine frameworks of meaning.

9.8 The Emerging Theory

Students are given an image of science and technology, which is deterministic, mechanistic and concerned with impersonal, factual knowledge. This is detrimental to the inclusion of values and valuing in the educative process. It might be assumed that the origins of such a view are teachers' constructs, knowledge, understanding and experience. The contradictions between personal and professional beliefs of educators in the sample suggest that this is not the case. The representations of science being presented to students does not seem to be primarily due to educators' ignorance or unfamiliarity with other views. Therefore it is not just a case of teacher education regarding different perspectives about the nature of science; however, it may be different in the case of technology. The lack of consensus about the nature of technology and technology education indicates a need to investigate and explore different perspectives. It is important however, to separate confusion about the nature of technology and technology education from the acknowledgement that technology is a value-laden activity.
Although it seems people are aware of differing perceptions of science, the epistemological view variously described as 'hard', mechanistic, deterministic science is the framework of meaning being applied uncritically. If this is the framework which is being used in technology education, technology teachers need to investigate their own, and others’ concepts, of the nature of science. Evaluation of feminist perspectives on science and technology and exploration of the relationship between science and technology is also required. This exploration will be influenced by the background of technology educators and will need to take cognisance of the fact that teachers with a scientific background have different experiences than those with CDT, Home Economics or Art and Design background.

9.9 Summary

Education is about change and providing more and different ways of viewing the world. I am concerned with appreciating different ways of perceiving and with changing the way science and technology education are taught in order to ensure that awareness of values is included. Crucial to this are philosophical or epistemological considerations. Such consideration facilitates understanding the nature and processes of technology, draws into the open constructs and beliefs for discussion, and hence there is the opportunity for deconstruction and reconstruction (Bearlin, 1987). Fullan and Stiegelbauer (1993) believe this process encourages respect and collaboration between colleagues, thus aiding implementation and evaluation of change in policy and in practice.

Clarification of beliefs and values is inherent in managing change (Fullan, 1993). This clarification has to take cognisance of i) the role and responsibility of the teacher, and ii) the beliefs they hold about what they are teaching. One way role perceptions and beliefs can be examined is through reflective practice (Schon, 1983).

The discrepancy between the personal and professional beliefs reminds me of the saying "don’t do as I do, but do as I say" or "don’t think as I do but think as I say you should". This is, in turn, reminiscent of the difference between espoused theory and theory in practice (Argyris, 1964). Examination of possible reasons for such a
discrepancy has to accept that any change depends on the willingness of people to take risks (Gilbert and Temple 1991), and taking risks is about learning to live with uncertainty (see section 9.3).

Reflection on personal practice and personal beliefs cannot be separated from reflections about the nature and aims of education. Sections 4.0 and 4.1 explored divergent views of education often described as traditional versus progressive education. Progressive and traditional is also translated as process and task (Heron, 1993) or process and curriculum content (Jarvis, 1988) particularly when applied to androgogy. Jarvis suggests that process involves attitudes and values, is not assessed and neither student or tutor are judged on attitudes and values. Curriculum content focuses on knowledge, and skills and is assessed from above and students and teachers are judged on results. Technology education involves content and process. The nature and aims of the processes are not always clear however. Process may be recognisable as prescriptive technology (McCormick et al 1994) or as designing and making in context. Kimbell (1992:1) is clear that concentrating on content alone, and adhering to traditional ways of teaching is counter-productive even when the goals are increased economic production.

The research findings indicate that since the introduction of the National Curriculum teachers have concentrated on factual content: curriculum has come to mean what should be taught. But content is only one aspect of curriculum. Aims and objectives, methods of teaching, learning, assessment and evaluation are equally important. Educators have to constantly reflect on why - the aims and objectives, how - the strategies for facilitating learning and constantly ask themselves: How do I know I and my students are achieving the identified aims to the best of our abilities? These are elementary components of any educational practice whether this is pedagogy or androgogy as in the education of teachers.

The next Chapter will focus on suggested changes in teacher education which may facilitate changes in science and technology education.
10.0 Introduction

The difference in educators' personal beliefs about the nature and aims of science and technology and the way they teach has been identified and reasons for the difference suggested (see sections 9.4 and 9.6). I have argued that the picture of science and technology being presented is not conducive to raising awareness of values and hence there is a need to change the way science and technology are taught. How this might be done is the main consideration in this Chapter.

Recalling the emerging theory discussed in section 9.10, I shall concentrate on the role of the teacher. First however, I shall try to address the confusion about technology and aims for technology education. In doing this I must reiterate that aims are inextricably linked with consideration of available resources, both human and physical, and with the approaches and strategies which might be used for teaching, learning, assessing and evaluating. All these elements are also connected with how the role and responsibility of educators is perceived.

10.1 The Confusion about Technology and Technology Education

I believe that aims for technology education in school need to be clarified for only when this has been done can educators be clear about their role. Evaluation, by students, educators, inspectors or other has to be carried out with reference to aims and criteria. Not knowing the goals to which one is apparently working, is a demotivating experience.

Throughout the thesis I have argued that technology has to be placed in context: this is, I think, more problematic for students in school and tertiary education than in higher education. If the aims and criteria for evaluation in design and making look only at the internal values of technology (fitting the intended purpose, durability, cost-effectiveness and marketability), then questions need to be asked about ensuring the interest and motivation of students. I wonder whether school technology which concentrates on
internal values can really be representative of industrial or commercial technology. Students who are expected to mimic commercial processes undergo a realistic, second-rate, sterile exercise which does not recognise student experiences and interests.

Ownership is important in establishing commitment to change (Fullan, 1993). In arguing for the aims to be clarified, I believe that technology teachers, or their appointed representatives, have to be involved. In saying this I am remembering that National Curriculum proposals are presented for consultation but this seems to be rather like "putting the cart before the horse": it is difficult to comment on programmes of study and statements of attainment without recourse to the underlying philosophy and aims.

In wanting educators to be involved in philosophical discussion I am assuming that:

- Technology educators can be identified;
- There are fora for engaging in discussion;
- There is professional representation;
- Educators wish to be involved.

The diversity of background of teachers and the variety of departmental frameworks in which teachers work mirrors the difficulty in defining technology. This diversity of experience could have been a strength but instead it seems to have added to the confusion and to have produced separation and entrenchment. I would hope the aims which resulted from discussion would reflect the experience and capabilities of all technologists.

Discussion is taking place in academic and professional publications, in educational establishments and at conferences but the number of persons directly involved is relatively small and most of the people are not practising teachers. Membership of the professional bodies such as DATA (Design And Technology Association) is also rather low which prevents powerful representation of teachers' views. In saying the above I acknowledge that Design and Technology is a relatively new area in the school curriculum and agreement on aims may be achieved in time.
10.2 Approaches to Teaching and Learning

If technology education in school is not to be a sterile exercise, pupils' motivations, experiences and interests have to be incorporated and this can be achieved if the external values are included (see section 9.5). Industrial or commercial understanding, typified by the reference to internal values, although sometimes possible in student's practical work, will often be best developed by strategies such as role play, simulation, debate, work experience and industrial visits.

10.3 Placing Science and Technology in Social, Cultural and Historical Contexts

Education which places technology in social, historical and cultural contexts becomes more complex but also more realistic. It also means that students and teachers are confronted by different beliefs, motivations and ways of interpreting experience: this is also true of cross-curricular work. Exploration of beliefs and motivations should lead to the realisation that economic factors are not the only criteria in determining quality.

Materials which describe and explain, in a non-patronising way, the technologies of less industrialised countries, are available: more are needed. These could be described as materials on the 'fringe' of technology education; the issues they raise need to be included in 'mainstream' textbooks.

Textbooks influence curricular content and teaching and learning strategies. Accounts of scientific and technological developments in textbooks rarely discuss the personal choices of scientists or technologists. The image is of a person distanced from the process and outcomes. Personal perception, instinct, imagination, motivation and feelings are omitted. It is possible, however, to obtain and adapt information from biographies and documentary/drama television programmes and to arrange discussions with practising male and female scientists and technologists from the less industrialised majority as well as the minority world. Discussions must be informal enabling students to ask, with permission, personal questions.

10.4 Practical Activities in Science and Technology

Interviewees said that the introduction of National Curriculum had led to less practical
science work, or at least less open-ended, investigative work. This is a retrograde step in promoting understanding, developing exploration of ways of perceiving and encouraging awareness of value judgements. It is nearly ten years since the Department of Education and Science (1985) stated that much science teaching consisted of pupils accumulating facts which had little to do with their experience and hence was not relevant to their daily lives. The Assessment of Performance Unit (APU) (1986) research indicated that 'recipe following' did little to enhance conceptual understanding. The evidence from this and other research (McCormick et al, 1994) suggests that much of the technology pupils experience in secondary school, is of the 'recipe following' rather than the problem-solving kind: the task is identified, defined and tightly controlled by the teacher. While acknowledging the influence of classroom management issues associated with relatively large numbers of pupils and insufficient resources, I believe the way practical work is carried out is related to teachers' perceptions of their role.

10.5 Beliefs and Approaches to Teaching
Awareness of teaching strategies, problem-solving activities and materials is only one aspect of changing practice. Whether, and how, materials are used, and whether educators collaborate with colleagues depends on educators' beliefs. McBrien (1994) investigated the influence of the teacher on pupils' perceptions of the technology of what he calls the Majority world. Whether students gain an impression of inferior technology by people who lack ability, or whether the impression is about injustice and respecting others depends on often subtle ways in which the teacher presents the material. Teachers' personal beliefs about majority world technology are transmitted subconsciously and are adopted by students.

The values behind the criteria Pitt (1991: 34-35) uses, for example "...deepen their [pupils] concern for the poor and those at the margins of society" are those of justice, peace, equality, responsibility, respect and concern for all people and, as he acknowledges, they arise from Judaeo-Christian beliefs. In the Quaker school in which he works such beliefs are promoted.
Pursuing educational practices from religious or political beliefs and teaching and inculcating particular value positions can be problematic. Teachers may present their own values as politically correct. In the Quaker school the belief system is explicit and open to critical analysis. The point I wish to make here is not which values and beliefs should be inculcated, this is beyond the remit of this thesis, but that beliefs are brought into the arena for discussion.

At this point in the discussion I wish to extrapolate from the specific (technology) to all teacher education. There are three reasons for doing this. First valuing and value judgements permeate all aspects of education (see section 4.0). Second, modifications in policy and practice are more likely to be implemented and to bring about meaningful change if the approach is cross-curricular and cross departmental. Although it has been argued that there is a particular problem in science and technology (illustrated by the prevalence of scientism and technicism), separating technology and science from other areas of human experience will encourage and reinforce this. Third, major perspectives on educational practice such as reflective practice and androgogy approaches are relevant across all teacher education. Educators' epistemological beliefs, frameworks of meaning, and beliefs about their role influence all teaching and learning regardless of subject and age of student.

10.6 The Role of the Teacher

Many of the suggestions I gave for the mismatch in personal and professional beliefs are related to the traditional view of the role of the teacher, i.e. as the authority and expert who has the true knowledge and the correct answers to problems which he or she can hand on (Jarvis, 1992). This view is exaggerated in science and by inference in technology, which are seen to be concerned with impersonal factual knowledge, finding answers, and which exclude moral judgements and emotional factors. It is not therefore surprising that the educators in the sample see their role as that of expert with the true knowledge. Much of their behaviour and thinking will no doubt be 'habitualised' (see section 1.9). Challenging assumptions, habitualised thinking and ways of working, should be part of all education especially teacher education and is at the heart of reflective practice.
10.7 The Reflective Practitioner

Changes in higher education in recent decades have involved moves towards self-directed, experiential and resource-based learning. Reflective practice in education is concomitant with such approaches. It is active learning which involves the whole person as a spiritual, thinking, feeling, choosing, energetic and physical being (Heron, 1989). Helping student and practising teachers to reflect on their existing and developing constructs about teaching and learning, should be an important aspect of teacher education. Constant reflection on practice is the essence of what it means to be professional, to be a practitioner who critically reflects on the meaning of their thoughts and actions (Schon, 1983). From such reflection come new ideas, theories and hence change. Regrettably my personal experience as an initial teacher education tutor and as a past student teacher, indicates that educating teachers to be reflective practitioners is not a priority.

Teachers are in positions of power for they influence the beliefs, values and motivations of their students who are the engineers, technologists, consumers and voters of the future. Avoiding the value issues in teaching technology is an abuse of this power. Constantly reflecting and sharing reflections is one way to counter this. Excluding value issues may be a consequence of maliciousness but usually is a result of good intention, for example not wishing to confuse students, or of unconscious habitualisation.

In teacher education curriculum content, methods and resources are examined for underlying or explicit ideologies such as racism or sexism. Technicism and scientism should be included. Personal ideologies and perceptions about the role of the educator have, in constructivist terms, to be elicited, deconstructed and possibly reconstructed. The experience of exposing and changing constructs can be uncomfortable, painful and hence, resisted (G. Kelly, 1955). Similarly, identifying the differences between espoused theory, or theory which is implicit, and theory in practice, which is explicit, (Argyris, 1964) may also be resisted. The experience of doing this, painful as it may be, is, nevertheless, necessary for practitioners who are professionals. Keeping theories implicit leads to misunderstanding, ineffective practice and rigid adherence to existing practice whereas making the theories explicit leads to understanding, and effective
practices which are open to change.

Espoused theory may be difficult to articulate as are beliefs (section 9.2) whereas theory in practice can be elucidated by observers and consequently used to probe practitioners' explanations for what they are doing. Exposing mismatches between what is believed and what is practised is important. It is about stepping back from what one is doing in order to evaluate, justify and modify one's practice. It is also about knowing the remit and boundaries of the professional role and being able to distance this from personal feelings, beliefs and motivations.

One of the most telling comments from interviewees was pupils' inability to accept uncertainties. While acknowledging the human desire for certainty (Perry, 1970; Fowler, 1981; Kohlberg, 1984; Hull, 1985), I wonder if there is a 'chicken and egg' situation operating here. If the only education a teacher has experienced has offered knowledge as immutable fact, then ways of making explicit and valuing controversy will not be within their experience. Hull (1985) writes of thought-stopping educational techniques commonly used to reduce critical awareness which is a good description of teaching which excludes awareness of values. Failing to challenge students' established constructs discourages learning. Hull is clear that people who believe they are right and do not engage in what he calls the 'pain of learning', have not learned to live with uncertainty and have stopped learning. Teachers have to remain life-long learners about their subject area, teaching and learning theory and practice, and about themselves.

Teachers are usually expert at teaching, but teaching separated from learning has no meaning. A supportive, learning culture typified by active, experiential approaches where student and tutor learn together and where the responsibility for learning is shared, does not arise by chance. Students and tutors have to learn to give and receive effective and helpful feedback. Such a culture requires students to be treated as adults, equal partners and active participants.

One way this can be done is to think in terms of androgogical and pedagogical approaches to teaching and learning.
10.8 Pedagogy and Androgogy

School teacher education is unique because it involves both androgogy (pertaining to adult education) and pedagogy. As adults, students should be learning with a milieu which upholds androgogical practice, but teacher education courses have components, often referred to as ‘professional studies’, which relate to pedagogy i.e. how children learn and how to aid this learning. It is not unusual for student teachers to be taught using pedagogical methods typified by delivering content and skills; something which is to be expected, given that most teacher educators only have experience of school teaching.

In recent years initiatives such as Enterprise in Higher Education, have tried to educate higher education lecturers in androgogical procedures such as facilitating and giving academic credibility to active, experiential learning and providing support to enable students to take responsibility for their learning. I believe there is a particular need for this in teacher educator establishments. Such establishments often illustrate the espoused theory and theory in action dilemma. Children are treated as physical entities to be moulded with little or no reference to their experience. The reasons for this are the expectations of the teacher, of the pupils themselves and of society. Adult students and tutors carry expectations of the educative process from their school experiences and find it hard to adjust. Pedagogy involves a power imbalance: children are expected to conform and rebellion leads to punishment. Adults are less likely to conform and will make clear their concerns and thoughts if they are in an environment which is open to ideas, is supportive, is mutually valuing, and which employs mutual consultation with respect for experience and expertise without abuse of power.

In promoting these ideas I am implying that teacher education is valued and that there is opportunity to change and be flexible. The polarities which described education in section 4.0 and 4.1 also apply in initial teacher training. Imposed government policies, for example the increase in the school experience component, do not seem to be about promoting a praxis approach and the development of critical practitioners.
10.9 The Need for Experience on which to Reflect
It would be remiss not to mention one of the problems of reflective practice. Students in initial teacher education often lack experience of being a teacher and people can only reflect on what they have experienced. Reflection is often encouraged following school experience (or what is sometimes called teaching practice) using 'critical incidents' or insights which students are asked to bring to sessions but feelings, values behind choices and decisions are rarely included. Lack of experience is not an issue in INSET provision. Here the problem is often expectations of participants and those who send them on courses: transmission of content and 'tips for teachers' are usually what are requested. If it is remembered that all student teachers have experience as learners then it is possible to engage in focused reflection.

10.10 Developing Self-awareness
Reflective practice can foster self-awareness and personal development. Both are important elements in teacher education. Knowing one's strengths and weaknesses helps people to know how to manage weaknesses and know when they are projecting onto others or taking the power of others because of such weaknesses. Growing self-awareness can be part of sharing reflections, for example, using self and peer assessment.

Texts about facilitation of self and peer assessment and promoting experiential learning are available. People have to learn facilitation by experiencing it (Heron, 1989). Skilled facilitation is essential: facilitators must be aware of participants' reluctance to share themselves as a strategy for self-management, particularly emotional. The only way to learn to manage group work is to learn in a group. Developing awareness of self as educator and private individual is pertinent to achieving congruence between espoused theory and theory in practice. It is also reminiscent of the starting point of this thesis. According to the evaluations I received after the INSET courses I tutored I was a successful, professional educator. Nevertheless the feeling that I should be addressing controversial issues increased until I was so uncomfortable with my practice that I started this research. Before finally reflecting on my personal experience I briefly list other important issues raised by the research.
10.11 Other Points Arising from the Research

In a thesis such as this it is impossible to address all the findings and implications arising from the research. Points which are worthy of mention but which cannot be addressed here are:

1. Meanings for the words 'objective' with particular reference to the views that scientific findings are influenced by personal gain and the need for continued funding. Further research could look for comparisons between objectivity in science and in technology.

2. Recalling the need for certainties and the use of the words 'fact' and 'proof', research is needed into the educative procedures by which people are enabled to cope with uncertainty.

3. Educators' reasons for teaching technology; this could also include identifying the human problems which technology can address.

4. Perceptions of design and its relationship with technology as applied science.

5. The inclusion of value issues in physical science education.

6. Student motivation when their areas of concern are ignored.

7. Comparison of students' beliefs about science and technology with teachers' beliefs.

8. Relationships between science and technology departments in schools and higher education institutions and facilitating collaboration between humanities and science and technology.

9. Teaching technology using a constructivist approach.
Reviewing my time as student in the 1970s and my years as a secondary school teacher, I now realise that my initial teacher training or subsequent INSET education, never addressed the needs I outlined in the Introduction to this thesis. As a student teacher, I received a 15-hour course on moral education, which did not include science and technology and was not related to the classroom situation. I also received a 15-hour course termed The History and Philosophy of Science which was presented in a factual, historical way e.g. presented the science of Aristotle or Popper's theories. Factual information was not related to the school experience, to the origins of the content I would teach in school or, more importantly, to the reasons why I would teach science. All my teacher education experience has been concentrated on how to teach but not on why. This is reminiscent of my teaching INSET participants biotechnological facts and skills without addressing the purpose or implications of certain procedures (discussed in the Introduction). It is also reminiscent of 'pure' science being concerned with how but not why. I could thus vindicate teaching value-free science.

It is hard to know why I became unhappy about transmitting a value-free image. It seems to have been a combination of growing awareness of biotechnological developments which more than any other area of science raise controversial matters; the publication of the initial National Curriculum Documents, which I found very challenging, and the move, as a tutor, into the academic environment of higher education. This latter opened my eyes to different ways of perceiving, gave me the opportunity to read widely and, more importantly, involved me in academic discussions where ideas were shared, challenged and developed. Surrounded in the early years by practising scientists who had moved into education, my assumptions about science were challenged and I learned to consciously value scientific thinking. This produced changes in my approach to teaching and in my image of myself as teacher.

I was doubly fortunate to find myself in a department concerned with andrology which emphasised active, experiential learning and self development. A praxis approach which
involved understanding theoretical underpinning and participation in a variety of courses, fostered my questioning of myself as learner and teacher and hence stimulated my development. With increased confidence and self-awareness, I was, after 15 years of teaching, aware that teaching has no meaning unless it is linked to learning by students and by the teacher. The adults with whom I worked brought their experience, concerns, expertise and abilities to a shared, mutual learning experience. Evaluation of learning became meaningful because it was open, constructive and reinforced or changed practice and the ownership of the curriculum was shared with students. This necessitated taking risks and as a tutor, which I sometimes found uncomfortable, painful and challenging. It was also the most rewarding teaching I had ever done.

Now, as a tutor in initial teacher education, I am aware that student teachers are treated as pupils not as adult students. Subject content and pedagogy are emphasised but developing self-awareness, critical reflection and epistemological and philosophical deliberations are not. Current students experience of initial teacher education is not very different from mine of twenty years ago except, perhaps, there is even less philosophical, historical and epistemological reflection.

This lack of reflection is most regrettable for present day education is handicapped by unchallenged assumptions about its role and remit: assumptions which arise at all levels from the Secretary of State and to the classroom teacher. If education is to be meaningful for students, educators and society, basic questions about aims have to be addressed and this is especially important in technology education. The introduction of the National Curriculum has meant educators have concentrated on the content to be taught and have neglected the educative process. During recent discussion on educational policy with practising teachers on who are students on a postgraduate course, they said they had no idea of the rationale behind the National Curriculum. Narrowing the discussion to specific subjects did not help. Technology teachers, for example had not read, or had forgotten, the rationale for technology education presented in the Interim report (1988). Many teachers no longer had copies of the early National Curriculum documents in various subject areas which had discussed the rationale.
Curriculum is more than 'academic' content. Teaching and learning strategies, assessment and evaluation procedures have to be used within different contexts. I have argued that technology have to be placed in context so that human differences, interactions and needs are included: the same is true of all education. Education is essentially purposeful communication and relationships between teacher and student and student and student. Facilitative communication is built on mutual respect, trust and openness where different beliefs, perspectives and interpretations can be critically evaluated. Teaching has no meaning unless it is defined in terms of learning. Educators must be clear about what they, as professionals, hope their students will learn. As educators of adults they must also share sharing their expectations with their students knowing that in doing so they are they are taking risks and are open to challenge.
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Questionnaire

If you find there is insufficient space for your comments, please continue writing on the back of the papers.

1. Do you agree with any of these statements? Please put a tick or cross at the end of the sentence.
   a. Science is about observing and explaining the world.
   b. Science involves discovering the facts of the natural world.
   c. Science is the only way to explain the world we experience.
   d. Scientific knowledge is superior, prestigious knowledge.
   e. Science is difficult to understand, only the most intelligent people can understand science.
   f. The pure scientist is only concerned to discover the truth.
   g. Scientists approach their work objectively, their feelings, wishes and personal attributes have nothing to do with the processes they carry out.
   h. Science deals in uncertainties, it offers the best explanation at the time.
   i. Scientific knowledge grows by accumulating facts.

2. We often talk of the laws of science. What do you understand by this term?

Are such laws true? How can we assess the validity of the laws? Is there a distinction between validity and truth? Please explain your answer.
3. Please circle the appropriate response

Superstition has nothing to do with science. Agree Disagree

Astrology has nothing to do with science. Agree Disagree

In time we will have scientific explanations for everything including phenomena such as ESP [extra-sensory perception]. Agree Disagree

Please write any comments you wish to add in response to the above statements in the space below:

4. Karl Popper was concerned about distinguishing myth' from science. A major criterion for Popper was that a scientific theory should be able to be tested and should be able to be rejected or refuted.

Can you explain the role of refutation in experimentation? Can you illustrate this using examples?

5. Philosophers have tried to analyse the processes of science. Some ideas put forward are:

Science is concerned with logic and proof, by logical reasoning true statements can be deduced.

By repeated investigation and observation of phenomena, the cause or effect of the phenomena can be found. The explanations of phenomena are then used to formulate laws and theories.

Scientists are reluctant to embrace new theories and explanations, rather they try to argue away observations which did not fit the established views.

Do you agree with any of these statements? Please comment below:
6. Science is concerned with hypotheses and theories. Are hypotheses and theories different? What do you understand by these terms?

How are these relevant in the scientific process?

Please give examples of hypotheses and theories in science.

7. Please circle the appropriate response:
   a) Do you ever try to discuss the nature of science with your students? Yes / No
   b) Do you ever discuss the nature of science with friends/acquaintances? Yes / No
   c) Have you any thoughts about how non-scientists friends and acquaintances view the work you do as a scientist or science educator? Please write your thoughts here.

8. What do you understand by the term metaphysics?

Can you give examples of metaphysical thought?

9. Please explain the following words, can you identify any distinguish between them? a) imagination b) intuition c) luck

How important do you see imagination, intuition and luck in scientific work?
Questionnaire on the Understanding of Science and Technology

Please CIRCLE the appropriate response.

A SCIENCE

1. Science is about observing and explaining the world.
   Strongly Agree  Agree  Disagree  Strongly Disagree

2. Science involves discovering facts about the natural world.
   Strongly Agree  Agree  Disagree  Strongly Disagree

3. Scientific knowledge is prestigious knowledge, (eg it has high value in the world and is seen as superior to other forms of knowledge)
   Strongly Agree  Agree  Disagree  Strongly Disagree

4. A scientist is concerned with discovering the truth.
   Strongly Agree  Agree  Disagree  Strongly Disagree

5. Scientists approach their work in an objective way, their feelings, and personal wishes and attributes have little to do with the processes they carry out.
   Strongly Agree  Agree  Disagree  Strongly Disagree

6. Science deals in uncertainties, it offers the best explanation for the time.
   Strongly Agree  Agree  Disagree  Strongly Disagree
7. Scientific knowledge grows by accumulating facts.

Strongly Agree  Agree  Disagree  Strongly Disagree

8. In time we will have scientific explanations to explain all known phenomena.

Strongly Agree  Agree  Disagree  Strongly Disagree

9. Science reflects traditional stereotypical male values.

Strongly Agree  Agree  Disagree  Strongly Disagree

10. Scientific laws are true statements about the world.

Strongly Agree  Agree  Disagree  Strongly Disagree

11. Scientific laws are discovered by scientists.

Strongly Agree  Agree  Disagree  Strongly Disagree

12. Any person engaged in science education has a responsibility to include social, ethical and moral issues in their teaching.

Strongly Agree  Agree  Disagree  Strongly Disagree

13. Research is about being precise, accurate and reliable. Only research which produces quantitative evidence is valuable.

Strongly Agree  Agree  Disagree  Strongly Disagree

B. TECHNOLOGY
1. Females are under-represented in physical sciences and engineering because there are innate differences between the sexes which means that girls are less able to cope with science and maths.

   Strongly Agree  Agree  Disagree  Strongly Disagree

2. I am aware of projects such as GIST (Girls into Science and Technology) and WISE (Women in Science and Engineering) have explored the under-representation of girls in science.

   Strongly Agree  Agree  Disagree  Strongly Disagree

3. I am familiar with the reasons for the underachievement of girls in science?

   Strongly Agree  Agree  Disagree  Strongly Disagree

4. I am familiar with the practical recommendations made by such projects.

   Strongly Agree  Agree  Disagree  Strongly Disagree

5. Due to knowledge of the recommendations of these projects, I have made changes in the way I teach physical science and/or technology.

   Strongly Agree  Agree  Disagree  Strongly Disagree

6. I always try to include social aspects of science and technology.
APPENDIX3  Version 3.

THIS IS A TRIAL QUESTIONNAIRE. Please follow the guidelines to complete the questionnaire.

Tick the statements with which you agree.

Place a cross next to those with which you disagree.

You may feel that none of the responses are appropriate - therefore please add any responses which you feel are important in the space provided.

1. Who should be given the authority to make decisions about the development and use of genetic engineering techniques -

   a. Scientists and engineers because they are the experts who know all the facts
   b. Scientists and engineers because they are not affected by political or national interests
   c. Scientists and engineers because they are the only people who know how their work can be used
   d. Scientists and engineers because they are not affected by personal interests
   e. ... others
   f. ... inventors
   g. ... thinkers, theologians and other academics
   h. The public because they are the people who will be affected...

Additional response:
2. Science is different from other areas of human thought because:

- It explains the nature of the universe
- It is concerned with discovering the laws of the universe
- It tries to explain observations about the universe
- It is the prime medium of explanation
- It is only concerned with producing new knowledge

Additional response:

3. Scientists:
- Are concerned with observing and explaining their observations.
- Produce explanations for events and then they carry out experiments to support their explanations.
- Produce explanations for events and then they carry out experiments to try to disprove their explanation.

Additional response:

4. Most scientists are:
- Only concerned with finding the truth.
- Concerned with the potential effects (both beneficial and harmful) of their work for the public.
- Choose their area of work because of the possible benefits of their work for the public.

Additional response:
5. Science and technology
   are separate areas of knowledge  A
   are interlinked  B
   are indistinguishable  C

Additional response:

6. Scientific models (such as models of the atom or of DNA) are:
   useful ways of explaining theories  A
   accurate representations of reality  B
   speculations about reality  C

Additional response:

7. When scientists disagree about something
   it is because one side does not have all the facts  A
   It is because they hold different moral values  B
   It is because they must bear in mind the need for support for their research  C
   It is because they are defending their own theories  D

Additional response:
8. In order to improve the quality of life we should:

- invest more money in science research (A)
- invest more money in technological research (B)
- (C)

Additional response:

9. Science can offer considerable help in resolving social problems like poverty, crime, unemployment and overpopulation (A)

- can be blamed for many social problems like poverty, crime, unemployment and overpopulation (B)
- is influenced by cultural factors such as food shortages, overpopulation, defence needs (C)

Additional response:

10. When scientists classify something like a plant according to its species, an element according to the periodic table.

- they are classifying nature as it really is (A)
- to do it any other way would be wrong (B)
- it is only one way of doing this, there may be many better ways of doing this (C)

Additional response:

11. When scientists

- carry out investigations correctly they discover knowledge that will not change (A)
- discover knowledge which later changes it is because their investigations were not done correctly (B)
- discover knowledge they accept it may later change even though their investigations were carried out correctly (C)
12. The best scientists work in a purely rational way. A
are not locked into any one scientific method B
use a variety of methods C
work by instinct and intuition D

Additional response:

13. Technology:

is a priority subject in education A
is of equal worth with all other areas of the curriculum B
should be a part of all children's education from age 5-16 C
should be taught only to those children who are interested D
and are able to understand

Additional response:

14. men

are able to think more rationally than women A
have the same abilities as women B
have influenced the processes of science and technology so C
that these are primarily masculine activities
are reluctant to examine the processes of science to encourage women D

Additional response:
19. Technology is a value-free activity
   because decisions are made for economic reasons
   because it is only when the products are used that values become involved.
   because it only applies knowledge and skills and these do not involve value judgements

   is statement which cannot be justified

Additional response:

19. Most people
   are unaware how the goods they buy are made
   look to technology to improve their standard of living
   feel that technological is moving too quickly

Additional response:

20. Social and value issues relating to technological developments
   are best discussed in science and technology lessons
   should not be discussed in school at all
   should be discussed in all areas of the curriculum
   should be discussed to present a more human side of science and technology

Additional response:
1. Technology:

   can offer considerable help in resolving social problems like poverty, crime, unemployment and overpopulation. [A]

   or many social problems like poverty, crime, unemployment and overpopulation can be blamed on technology. [B]

   is influenced by cultural factors such as food shortages, overpopulation, defence needs. [C]

   additional response:

2. Science

   is a priority subject in education. [A]

   is of equal worth with all other areas of the curriculum. [B]

   should be a part of all children's education from age 5-18 years. [C]

   should be taught only to those children who are interested and are able to understand. [D]

   additional response:

   Please explain in a few sentences how you are involved in science, science education / technology / technology education.

   Please tick the appropriate box:

   teach students 5-11yrs 11-16yrs 16-19 yrs over 19yrs

   have a degree related to:
   Science  Physics  Chemistry  Biology  Other (please state)

   am actively involved in science research

   Please return this questionnaire to:
   Signe Riggs Department of Educational Studies, University of Surrey Guildford GU2 5XH
THIS IS A TRIAL QUESTIONNAIRE. Please follow the guidelines to complete the questionnaire by underlining one of the responses. If you cannot agree or disagree please do not respond. (or agree disagree)

1. Scientists and engineers should be given the authority to make decisions about the development and use of radiation because they are the people who know the facts the best.

   Strongly Agree  Agree  Disagree  Strongly Disagree

1.2. Scientists and engineers should be the last people to be given the authority to decide about the development and use of radiation. Because the decisions may affect many people, the public should be the ones to decide.

   Strongly Agree  Agree  Disagree  Strongly Disagree

2.1. Most scientists and technologists are concerned with the potential effects (both helpful and harmful) that might result from their discoveries.

   Strongly Agree  Agree  Disagree  Strongly Disagree

2.2. Most scientists and technologists are not concerned with the potential effects (both helpful and harmful) that might result from their discoveries.

   Strongly Agree  Agree  Disagree  Strongly Disagree

3. Scientists are not really affected by the political climate in Britain, because they work in particular institutions and are pretty much isolated from society.

   Strongly Agree  Agree  Disagree  Strongly Disagree

3.2. Scientists are affected by the political climate in Britain, because they are an integral part of British society.

   Strongly Agree  Agree  Disagree  Strongly Disagree
4.1 Science and technology have little to do with each other.

Strongly Agree  Agree  Disagree  Strongly Disagree

4.2. Technology gets ideas from science and science gets new processes and instruments from technology.

Strongly Agree  Agree  Disagree  Strongly Disagree

5.1. Many scientific models (such as the model of the atom or of DNA) are metaphors or useful stories; we should not believe that these models are duplicates of reality.

Strongly Agree  Agree  Disagree  Strongly Disagree

5.2. Many scientific models (such as the model of the atom or of DNA) are accurate duplicates of reality, that these models are duplicates of reality.

Strongly Agree  Agree  Disagree  Strongly Disagree

6.1. When scientists disagree on a matter (e.g. on Mad Cow disease), they disagree mostly because one side does not have all the facts.

Strongly Agree  Agree  Disagree  Strongly Disagree

6.2. When scientists disagree on a matter (e.g. on Mad Cow disease), they disagree mostly because of different moral values.

Strongly Agree  Agree  Disagree  Strongly Disagree
6.3. When scientists disagree on a matter (e.g., on Mad Cow disease), they disagree mostly because of different motives (e.g., pleasing their employers or wanting research grants from the government.

Strongly Agree Agree Disagree Strongly Disagree

7.1. In order to improve the quality of life, it would be better to invest money in technological research rather than scientific research.

Strongly Agree Agree Disagree Strongly Disagree

7.2. In order to improve the quality of life, it would be better to invest money in scientific research rather than technological research.

Strongly Agree Agree Disagree Strongly Disagree

8.1 Although advances in science and technology may help improve living conditions, science and technology offer little help in resolving social problems like poverty, crime, unemployment, and overpopulation.

Strongly Agree Agree Disagree Strongly Disagree

8.2 Science and technology offer a great deal of help in resolving social problems like poverty, crime, unemployment, and overpopulation.

Strongly Agree Agree Disagree Strongly Disagree

8.3 Many social problems like poverty, crime, unemployment, and overpopulation are the result of scientific and technology developments.

Strongly Agree Agree Disagree Strongly Disagree
8.4 It is wrong to blame science and technology for many social problems like poverty, crime, unemployment, and overpopulation.

Strongly Agree Agree Disagree Strongly Disagree

9.1 The government should give scientists research money only if they can show that their research will improve the quality of living in Britain.

Strongly Agree Agree Disagree Strongly Disagree

9.2 The government should give scientists research money to explore the unknowns of nature and the universe.

Strongly Agree Agree Disagree Strongly Disagree

10.1 Communities or government agencies should not tell scientists what problems to investigate because scientists themselves are the best judges of what needs to be investigated.

Strongly Agree Agree Disagree Strongly Disagree

10.2 Communities or government agencies should tell scientists what problems to investigate; otherwise scientists will investigate only what is of interest to them and not necessarily investigate the problems of interest to the country.

Strongly Agree Agree Disagree Strongly Disagree
11.1 When scientists classify something (e.g., a plant according to its species, an element according to the periodic table, or energy according to its source), they are classifying nature according to the way nature really is; any other way would simply be wrong.

Strongly Agree  Agree  Disagree  Strongly Disagree

11.2 When scientists classify something (e.g., a plant according to its species, an element according to the periodic table, or energy according to its source), they are classifying nature according to a scheme which was originally created by other scientists; thus there could be many better ways of classifying nature.

Strongly Agree  Agree  Disagree  Strongly Disagree

12.1 When scientists investigations are done correctly, scientists discover knowledge that will not change in future years.

Strongly Agree  Agree  Disagree  Strongly Disagree

12.2 Even when scientists investigations are done correctly, the knowledge they discover may change in the future.

Strongly Agree  Agree  Disagree  Strongly Disagree

13.1 The best scientists are those who follow the steps of the scientific method.

Strongly Agree  Agree  Disagree  Strongly Disagree

13.2 The best scientists are those who do not lock themselves into following the steps of the scientific method, but instead use any approach that might help them.

Strongly Agree  Agree  Disagree  Strongly Disagree
14.1 Technology is the application of scientific knowledge.
   Strongly Agree  Agree  Disagree  Strongly Disagree

14.2 Technology is about finding appropriate solutions to human problems.
   Strongly Agree  Agree  Disagree  Strongly Disagree

15.1 Technology is a value-free process. Values issues are only involved when decisions are made about the use of the technology.
   Strongly Agree  Agree  Disagree  Strongly Disagree

15.2 Technology is human activity. Value issues are therefore involved in all aspects of technology.
   Strongly Agree  Agree  Disagree  Strongly Disagree

16.1 Technology is about improving the standard of living of a few people.
   Strongly Agree  Agree  Disagree  Strongly Disagree

16.2 Technology is about improving the standard of living of all people.
   Strongly Agree  Agree  Disagree  Strongly Disagree

17.1 Few people have any understanding of how the goods they buy are made.
   Strongly Agree  Agree  Disagree  Strongly Disagree

17.2 Most people understand how the goods they buy are made.
   Strongly Agree  Agree  Disagree  Strongly Disagree

18.1 Technology is primarily about looking for new opportunities for making and selling goods to as many people as possible.
   Strongly Agree  Agree  Disagree  Strongly Disagree
18.2 Technology is primarily about the technologist achieving personal satisfaction by designing and making a product.

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

19.1 In the future science and technology will find answers to most of our current environmental problems.

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
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</thead>
</table>

19.2 The use of science and technology is not the way to solve our current environmental problems.

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
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</table>

20.1 If science and technology teachers involve discussion about values in their lessons, there is a danger that students will develop anti-industrial feelings.

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
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</thead>
</table>

20.2 If science and technology teachers involve discussion about values in their lessons, industry will be seen in a more humane way. This will help to encourage young people into industry.

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>

21.1 Men and women have different abilities. Men are therefore far more able to be scientists and technologists.

<table>
<thead>
<tr>
<th>Strongly Agree</th>
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<th>Disagree</th>
<th>Strongly Disagree</th>
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</table>

21.2 Men and women have the same abilities. There are fewer women than men in science and technology because science and technology are predominately masculine activities.

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
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</thead>
</table>

21.3 Men and women have the same abilities. There are fewer women than men in science and technology because of the way society has defined the role of women.
<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.1 Technology is able to solve most human problems.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>22.2 Technology is about looking for appropriate solutions to some human problems.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>23.1 Technology is applied science.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>24.2 Technology is very different from science. Technology is always purposeful.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>24.3 Science and technology have the same aims.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>25.1 Science and technology must be priority subjects in education.</td>
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<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>25.2 Science and technology are of equal worth with all other areas of the curriculum.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>26.1 It is not the responsibility of science and technology teachers to teach about the political, economic and industrial influences on technology.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>26.2 Although it is not the responsibility of science and technology teachers to teach about the political, economic and industrial influences on technology, this must be included in other areas of the curriculum.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
27.1 Science and technology are intimately linked with military power.

27.1 Military power plays a very minor role in science and technology.

28.1 Scientific knowledge enables people to make predictions about the future.

28.2 Scientific knowledge provides people with the most reliable means for predicting the future.

28.3 Scientific knowledge cannot help in predicting the future.

29.1 Given sufficient time, science will be able to explain all known phenomena.

29.2 Science will never be able to explain all known phenomena.

30.1 Most human problems can be solved by technology.

30.2 Most human problems are beyond the realm of technology.

31.1 Science deals only in repeatable, measurable observations, there is no room for speculation.
<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.2 An important part of science is intuition and imagination.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>32.2 Technology enables us to control our environment to a great extent.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>32.2 Technology enables us to modify our environment.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>33.1 Technology is an activity which should include all areas of the curriculum.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>33.2 Technology should only be taught by technology teachers.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
</tbody>
</table>
Please explain in a few sentences how you are involved in science / science education / technology / technology education.

Please tick the appropriate box:

I teach students 5-11yrs 11-16yrs 16-19 yrs over 19 years

I have a degree related to:

Science Physics Chemistry Biology Other (please state)

I am actively involved in science research.

Please return this questionnaire to:

Anne Riggs Department of Educational Studies, University of Surrey Guildford GU2 5XH
APPENDIX 3 Version 5

THIS IS A TRIAL QUESTIONNAIRE. Please follow the guidelines to complete the questionnaire.

Please tick any of the following statements with which you agree

1. The people who should (make) the decision about the use of nuclear energy are:
   - Elected representatives and civil servants ✓
   - Philosophers, theologians and other academics ✓
   - The public because they are the people who will be affected ✓
   - Scientists and engineers ✓

Please tick one of the following statements.

2. Scientists are not really affected by the political and cultural factors because they work in particular institutions and are pretty much isolated from society.
   - Agree ✓
   - Cannot say
   - Disagree ✓

3. Scientists are affected by the political climate in Britain, because they are an integral part of British society.
   - Agree ✓
   - Cannot say
   - Disagree

4. Science and technology have little to do with each other.
   - Agree ✓
   - Cannot say
   - Disagree ✓

5. Technology gets ideas from science and science gets new processes and instruments from technology.
   - Agree ✓
   - Cannot say
   - Disagree

6. Science is the basis of all technological developments.
   - Agree ✓
   - Cannot say ✓
   - Disagree

7. Many scientific models (such as the model of the atom or of DNA) are metaphors or useful stories; we should not believe that these models are duplicates of reality.
   - Agree ✓
   - Cannot say
   - Disagree
8. Many scientific models (such as the model of the atom or of DNA) are duplicates of reality.

Agree Cannot say Disagree ✓

Please tick any statements with which you agree

9. Science is different from other areas of human thought because:

- It explains the nature of the universe A
- It is concerned with discovering the laws of the universe B ✓
- It tries to explain observations about the universe C ✓
- It is the prime medium of explanation (of what?) D
- It is only concerned with producing new knowledge E
- It is concerned with making precise measurements F ✓

You may feel that there are other factors which should be considered: please add any additional responses which you feel are important. This is a very difficult question to answer.

Please tick any statements with which you agree

10. Scientists and engineers should be given the authority to make decisions about the development and use of genetic engineering techniques because

- they are the experts who know all the facts A
- they are not affected by political or national interests B ✓
- they are the only people who know how their work can be used.
- they are not affected by personal interests D

This question appears to make the assumption that scientists and engineers should be given authority...
You may feel that there are other factors which should be considered: please add any additional responses which you feel are important.

Please tick any statements with which you agree.

11. A Scientists:
   Are concerned with observing and explaining their observations. ☑

   Produce explanations for events and then they carry out experiments to support their explanations. ☑

   Produce explanations for events and then they carry out experiments to try to disprove their explanation. ☑

   Carry out observations, collect data and develop hypotheses which they then attempt to prove. ☑

   Only concerned with finding the truth. ☑

Choose their area of work because of the possible benefits of their work for the society. Some do, many don't.

You may feel that there are other factors which should be considered: please add any additional responses which you feel are important.

Again difficult to give black or white answers. One could spend hours discussing each point. I could have almost as easily ticked none as all depending on how I interpreted the question.

Please tick one of the following statements.

12. In order to improve the quality of life, it would be better to invest money in technological research rather than scientific research.

   Agree ☐   Cannot say ☑   Disagree ☐
13. In order to improve the quality of life, it would be better to invest money in scientific research rather than technological research.

   Agree   Cannot say   Disagree

14. Although advances in science and technology may help improve living conditions, science and technology offer little help in resolving social problems like poverty, crime, unemployment, and overpopulation.

   Agree   Cannot say   Disagree

15. Science and technology offer a great deal of help in resolving social problems like poverty, crime, unemployment, and overpopulation.

   Agree   Cannot say   Disagree

16. Many social problems like poverty, crime, unemployment, and overpopulation are the result of scientific and technology developments.

   Agree   Cannot say   Disagree

17. It is wrong to blame science and technology for many social problems like poverty, crime, unemployment, and overpopulation.

   Agree   Cannot say   Disagree

18. The government should give scientists research money only if they can show that their research will improve the quality of living in Britain.

   Agree   Cannot say   Disagree

19. The government should give scientists research money to explore the unknowns of nature and the universe.

   Agree   Cannot say   Disagree
Please tick any statements with which you agree

20. When scientists disagree about something

- it is because one side does not have all the facts ✓
- it is because they have different interpretations of the facts
- It is because they hold different moral values /
- It is because they must bear in mind the need for support for their research
- It is because they are defending their own theories /

You may feel that there are other factors which should be considered: please add any additional responses which you feel are important.

21. When scientists classify something like a plant according to its species, an element according to the periodic table.

- they are classifying nature as it really is to do it any other way would be wrong ✓
- it is only one way of doing this, there may be many better ways of doing this.
- they are classifying nature according to a scheme which was created by another scientist.

Please tick one of the following statements.

22. When scientists

- carry out investigations correctly they discover facts that will not change in future years ✓
- discover facts which later changes it is because their investigations were not done correctly
- find out things about reality which they accept may later change even though their investigations were carried out correctly.
Please tick one of the following statements.

23. Technology is the application of scientific knowledge.
   Agree  Cannot say  Disagree

24. Technology is about finding appropriate solutions to human problems.
   Agree  Cannot say  Disagree

25. Values issues are involved only when decisions are made about how the technology is to be used.
   Agree  Cannot say  Disagree

26. Technology is human activity. Value issues are therefore involved in all aspects of technology, in designing, planning, and in making.
   Agree  Cannot say  Disagree

27. Few people have any understanding of how the goods they buy are made.
   Agree  Cannot say  Disagree

28. Most people understand how the goods they buy are made.
   Agree  Cannot say  Disagree

29. Technology is primarily about looking for new opportunities for making and selling goods to as many people as possible.
   Agree  Cannot say  Disagree

30. Technology is primarily about the technologist achieving personal satisfaction by designing and making a product.
   Agree  Cannot say  Disagree

Please tick any statements with which you agree.

31. The best scientists
work in a purely rational way.
are not locked into any one scientific method ✓
use a variety of methods ✓
work by instinct and intuition

You may feel that there are other factors which should be considered: please add any additional responses which you feel are important.

The best scientists will work both by instinct and in a rational way.

Please tick any statements with which you agree

32. Technology is concerned with
   - computers ✓
   - machines, cars, engines, aeroplanes etc ✓
   - pottery ✓
   - cooking ✓
   - gardening ✓
   - brewing and baking ✓
   - pre-natal screening ✓

You may feel that there are other factors which should be considered: please add any additional responses which you feel are important.

Please tick one of the following statements.

33. Technology:
   - is a priority subject in education ✓
   - is of equal worth with all other areas of the curriculum
   - should be a part of all children's education from age 5-16 years
   - should be taught only to those children who are interested and are able to understand

NB Technology in N.C. is not the same as what most people would see as technology

i.e. engineering

NB0
Please tick one of the following statements.

34. men

are able to think more rationally than women.

have the same abilities as women.

have had an influence on science becoming primarily a masculine activity.

have influenced the way technology is done so that it is primarily a masculine activity.

Please tick one of the following statements.

35. Women

are not intellectually suited to science.

are not intellectually suited to technology.

are reluctant to be scientists and technologists partly because of the way society has defined the roles of women partly because of the impersonal nature of science and technology presented.

Please tick one of the following statements.

36. Technology

enables us to control our environment to some extent.

enables us to change our environment.

is primarily about individuals achieving personal satisfaction by designing and making a product.

is primarily about looking for new opportunities for making and selling goods to as many people as possible.

Please tick one of the following statements.

37. Technology is a value-free activity
because decisions are made for economic reasons

because it is only when the products are used that values become involved.

because it only applies knowledge and skills and these do not involve value judgements

is statement which cannot be justified

Please tick one of the following statements.

39. Social and value issues relating to technological developments

are best discussed in science and technology lessons

should not be discussed in school at all

should be discussed in all areas of the curriculum

Please tick one of the following statements.

39. Science is intimately linked with military power.

Strongly Agree Agree Disagree Strongly Disagree

40. Technology is intimately linked with military power.

Strongly Agree Agree Disagree Strongly Disagree

41. In the future science will find answers to most of our current environmental problems.

Agree Cannot say Disagree

42. We will find solve our current environmental problems by technological means.

Agree Cannot say Disagree

43. If science teachers and technology teachers involve discussion about social and value issues in their lessons, there is a danger that students will develop anti-industrial feelings.

Agree Cannot say Disagree

44. If science teachers and technology teachers involve discussion about social and value issues in their lessons, students will be able to discuss industry in a rational and realistic terms.

A32
Agree  Cannot say  Disagree

45. If science teachers and technology teachers involve discussion about social and value issues in their lessons, industry will be seen in a more humane way. This will help to encourage young people into industry.

Agree  Cannot say  Disagree

Please tick one of the following statements.

46. Scientific knowledge enables people to make predictions about the future.

Please tick one of the following statements.

47. Given sufficient time, science will be able to explain all known phenomena.

48. Science will never be able to explain all known phenomena.

49. Scientists should be concerned with the potential effects (both helpful and harmful) that might result from their discoveries.

50. Scientists should not be concerned with the potential effects (both helpful and harmful) that might result from their discoveries.
If you are willing to take part in an interview for about 30 minutes please give your name and a contact address and telephone number.

Name

Address

Telephone number

Please return this questionnaire to:
Anne Rigg, Department of Educational Studies, University of Surrey, Guildford GU2 5XH 0483 300800 Ext 2165

With very many of the questions I did not want to commit myself by ticking any response.

Perhaps something like "please tick the comment which you believe to be closest to your opinion" is less threatening.

Also it takes ages to do properly - for many it would be possible to tick almost all or almost none.
Please complete the questions below by filling in the blank spaces or by putting a tick at the side of the appropriate responses.

1. Personal details

   - Male
   - Female

   - Age
     - 20-30
     - 30-40
     - 40-50
     - 50-60
     - 60-70
     - 70 plus

2. I have a qualifications related to -
   - Science
   - Physics
   - Chemistry
   - Biology
   - Engineering
   - Other (please state)

3. I am actively involved in science research -
   - Yes
   - No

4. I am involved in teaching -
   - Science
   - Science education
   - Technology
   - Technology education
   - Other (please explain)

5. I teach students aged -
   - 5 - 12 years
   - 12 - 16 years
   - 16 - 19 years
   - Undergraduates
   - Other (please explain)

Can more than one tick be used in each question?
IS A TRIAL QUESTIONNAIRE. Please follow the guidelines to complete it. For each of the following statements please tick the box which correspond most closely to your opinion on the statement. Please tick one box only for each question or statement unless directed otherwise.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientists are not really influenced by national politics because they work in particular institutions and are pretty isolated from society</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Neither agree nor disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>If science teachers and technology teachers involve discussion about social and value issues in their lessons, students will be able to discuss industry's place in society in rational and realistic terms</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Neither agree nor disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>The models used in science (such as the model of the atom or of DNA) are duplicates of reality</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Neither agree nor disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>Science and technology have little to do with each other</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Neither agree nor disagree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>Science differs from other areas of human activity because: (Tick as many boxes as applicable)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It explains the nature of the universe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is concerned with discovering the laws of the universe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It tries to explain observations about the universe</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is the most adequately tested medium of explanation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is only concerned with producing new knowledge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is concerned with making precise measurements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q6 Technology gets ideas from science and science gets new processes and instruments from technology

Q7 Technology is primarily about looking for new opportunities for making and selling goods

Q8 In order to improve the quality of life, it would be better to invest money in technological research rather than scientific research

Q9 Do you think that scientists and engineers should be given the authority to make decisions about the development and use of genetic engineering techniques?

If you have answered yes please give your reasons (Tick as many boxes as applicable)

- They are the experts who know all the facts
- They are not affected by political or national interests
- They are the only people who know how their work can be used
- They are not affected by personal interests
- They have the expert knowledge to express responsibility

Q10 Technology enables us to control our environment

Q11 (Tick as many boxes as applicable) Scientists:

- Are concerned with observing and explaining their observations
- Produce explanations for events and then they carry out experiments to support their explanations
- Produce explanations for events and then they carry out experiments to try to disprove their explanation
- Carry out observations, collect data and develop hypotheses which they then attempt to prove.
- Are concerned with finding the truth
- Choose their area of work because of the possible benefits of their work for the society.
Q20 (Please tick any of the following statements with which you agree)
I think that men:

- Are able to think more rationally than women
- Have influenced the way science is done so that it is primarily a masculine activity
- Have influenced the way technology is done so that it is primarily a masculine activity

Q21 If science teachers and technology teachers involve discussion about social and value issues in their lessons, the role of industry in society will be seen in a more positive light. This will help to encourage young people into industry

Q22 Technology is the application of scientific knowledge

Q23 (You may tick more than one of the following statements)
Technology:

- Is a priority subject in education
- Is of equal worth with all other areas of the curriculum
- Should be a part of all children's education from age 5-18 years
- Should be taught only to those children who are interested and are able to understand

Q24 Values issues are involved only when decisions are made about how technology is to be used

Q25 Few people have a clear understanding of how the goods they buy are made

Q26 Many social problems like poverty, crime, unemployment and overpopulation are the result of scientific and technology developments

Q27 Technology is primarily about the technologist achieving personal satisfaction by designing and making a product
28 (You may tick more than one of the following statements)
The best scientists

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work in a purely rational way</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Are not locked into any one scientific method</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Use a variety of methods</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Work by instinct and intuition</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

129 Judgements which take into account value issues are involved in all aspects of technology, in designing, planning, and in making

130 The government should give scientists research money only if they can show that their research will improve the quality of living in Britain

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Agree</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Disagree</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

131 (You may tick more than one of the following statements)
Technology is about:

<table>
<thead>
<tr>
<th>Technology is about:</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computers</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Machines: cars, engines, aeroplanes etc</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Pottery</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Gardening</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Brewing and Baking</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Pre-natal screening</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

132 (You may tick more than one of the following statements)
I think women:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are not intellectually suited to science</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Are not intellectually suited to technology</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Are reluctant to be scientists and technologists because of the way society has defined the role of women</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Are reluctant to be scientists and technologists because of the way science and technology is carried out</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

133 Technology enables us to change our environment

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Agree</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Agree</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Neither agree nor disagree</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Disagree</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
Q34 Do you agree that the practice of technology is a value-free activity?

If you have answered yes, please give your reasons
(Tick as many boxes as applicable)
Technology is value-free:

Because decisions are made for economic reasons
Because it is only when the products are used that values become involved
Because it only applies knowledge and skills and these do not involve value judgements

Q35 Decisions about the use of nuclear energy are made by the following people:
(Tick as many boxes as applicable)
Elected representatives and civil servants
Philosophers, theologians and other academics
The public
Scientists and engineers

Q36 Science is intimately linked with military power

Q37 We will solve our current environmental problems by the use of new technologies

Q38 When scientists carry out investigations correctly they discover facts which they accept may later change

Q39 If science teachers and technology teachers involve discussion about social and value issues in their lessons, there is a danger that students will develop anti-industrial feelings

Q40 Technology is about finding appropriate solutions to human problems
Q47 I have qualifications related to:

Science
Physics
Chemistry
Biology
Technology
Engineering
Education
Other (please state)

Q48 I am actively involved in science or engineering research

Yes
No

Q49 I am involved in teaching:

Science
Science Education
Technology
Technology Education
Other (please explain)
Not involved in teaching

Q50 I teach students aged

5 - 12 years
12 - 16 years
16 - 19 years
Undergraduates
Other (please explain)

If you are willing to take part in an interview for about 30 mins please give your name and a contact address and telephone number.

Name
Address

Telephone number

Please return this questionnaire to:
Anne Riggs  Department of Educational Studies,
University of Surrey, Guildford  GU2 5XH
0483 300800 Ext 3165
Q 17. When scientists carry out investigations correctly they discover facts that will not change in future years. Agree

Q 18. Scientists should be concerned with the potential effects (both helpful and harmful) that might result from their discoveries. Agree

Q 19. Men have influenced the way science is done so that it is primarily a masculine activity. Agree

Q 20. In general women and men have the same intellectual abilities which means they are both equally able to be scientists and technologists. Agree

Q 21. In general women are reluctant to be scientists and technologists because of the way society has defined the role of women. Agree

Values are a consequence of people's perceptions and beliefs. They are those things held to be of worth, and are used, often unconsciously, when making decisions. Values may be ideals such as justice, freedom, integrity or customs and institutions. They are closely linked with principles, ethics and morals.

Q 22. Social and value issues relating to technological developments should not be discussed in school at all Agree

are best discussed in science and technology lessons Disagree

should be discussed in all areas of the curriculum Agree

Q 23. Values issues are involved only when decisions are made about how technology is to be used. Agree

Q 24. If science teachers and technology teachers include discussion about social and value issues in their lessons, industry will be seen in rational and realistic terms. Agree
Q 25. If industry is seen in more rational and realistic terms. This may help to encourage young people into industry.

Q 26. Technology should be a part of all childrens' education from age 5 years.

Q 27. Few people have a clear understanding of how the goods they buy are made.

Q 28. Please tick as many boxes as you think are appropriate.

Decisions about whether nuclear energy is used to produce electricity are made by the following people:

- Elected representatives and civil servants
- Philosophers, theologians and other academics
- Industrialists
- The public
- Scientists and engineers

Q 29. Please tick as many boxes as you think are appropriate.

The people who should make decisions about whether nuclear energy is to be used to produce electricity are:

- Elected representatives and civil servants
- Philosophers, theologians and other academics
- Industrialists
- The public
- Scientists and engineers

Please add any additional comments you wish to make about any of the above statements. Do not be constrained by the lack of space for comment, please attach additional papers if you wish.
Question 3 about models of the atom and DNA being duplicates of reality was not clear. This was accepted but it was kept in the questionnaire to enable the understanding of models to be probed at interviews. It was thought possible that technology teachers, who work constantly with models and modelling may have a different understanding of 'scientific models' than science teachers.

Question 4 was removed everyone had disagreed with this.

Question 5 was reconstituted as questions 8 -12 to aid analysis and discussion at interview.

Question 6 was removed, everyone had agreed with this.

In Question 9 the word engineers was changed to technologist in order to be consistent.

The word can was changed to could in question 12

Question 14 was removed, this was too similar to question 8 and people all said neither agree nor disagree.

Question 15 removed - it was said to be too confusing, it could also be said to repeat the underlying premise of question 1.

Question 16 removed - again said to be confusing, at this stage of questionnaire design it was difficult to see how this helped with understanding beliefs about science.

Question 18 and 36 were removed - these were considered to be a leading questions and people were given the opportunity to comment on if they so wished.

Questions 20 and 32 concerned with gender were substantially changed. The responses to these questions were very negative, no one would complete statements about intellectual capability. The question about intellect is still included but it is hoped it is now more acceptable.

Removed the word overpopulation from question 26 - it is of a different order to the rest of the factors.

Question 27 removed - I was always unsure about this thinking it to be a 'weak' question.

Question 28 and question 11 were combined to make the new question 13

Question 29 was removed for it was thought that a response could be obtained from question 23 on the new questionnaire.

Question 30 was poorly answered and thought that a response could be obtained from question 1 on new questionnaire.

Question 31 - unsure that this question tells me anything so removed.
Question 33 - it was hard to disagree with this statement, so removed.

Question 34 - people confused as to meaning of values hence removed. I would have liked to ask people what they understand by values issues but this is too difficult. I decided to explain what I mean by values so that the questions which follow are not so ambiguous. There is confusion and I cannot interpret results unless people understand values. Changed the wording of questions 35 and 45 nuclear energy is too broad. Qualified this by adding used to produce electricity. Due to suggestions by respondents added industrialists.

Question 39 rearranged as new questions 24, 25,

Question 41, confusion about what is meant by future and to make it more specific would make it a leading question, hence it was removed.
APPENDIX 5

SCIENCE AND TECHNOLOGY EDUCATION AND ISSUES OF VALUE

Please return to: Anne Rigg, Lecturer in Science Education, FREEPOST, Department of Educational Studies University of Surrey, Guildford GU2 5XH (see enclosed)

For each of the following statements please tick only the boxes which apply.

Questions about Science | Agree | Undecided | Disagree
--- | --- | --- | ---
Q 1. Given sufficient time, science will be able to explain all known phenomena. |  |  | 4
Q 2. Many scientific models (such as the model of the atom or of DNA) are duplicates of reality. |  |  | 5
Q 3. Scientists are not really influenced by politics because they work in particular institutions and are pretty much isolated from society. |  |  | 6
Q 4. When scientists carry out investigations correctly they discover facts that will not change in future years. |  |  | 7
Q 5. Scientists should be concerned with the potential effects (both helpful and harmful) that might result from their discoveries. |  |  | 8
Q 6. Men have influenced the way science is done so that it is primarily a masculine activity. |  |  | 9
Q 7. The government should give scientists research money to explore the unknowns of nature and the universe. |  |  | 10
Q 8. Science is different from other areas of human thought. |  |  | 11
Q 9. Science is concerned with discovering the laws of the universe. |  |  | 12
Q 10. Science tries to explain observations about the universe. |  |  | 13
Q 11. Science is the most adequately tested medium of explanation. |  |  | 14
Q 12. Science is concerned with making precise measurements. |  |  | 15

A51
For each of the following statements please tick only the boxes which apply.

Q 13. Scientists

<table>
<thead>
<tr>
<th>Agree</th>
<th>Undecided</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are concerned with observing and explaining their observations.</td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>Produce explanations for events and then they carry out experiments to support their explanations.</td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>Produce explanations for events and then they carry out experiments to try to disprove their explanation.</td>
<td></td>
<td>18</td>
</tr>
<tr>
<td>Carry out observations, collect data and develop hypotheses which they then attempt to prove.</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>Are concerned with finding the truth.</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Choose their area of work because of the possible benefits of their work for society.</td>
<td></td>
<td>21</td>
</tr>
<tr>
<td>Are flexible and adaptable in the way they work and are willing to try many different methods.</td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>Work by instinct and intuition</td>
<td></td>
<td>23</td>
</tr>
</tbody>
</table>

Q 14. When scientists disagree about a scientific matter it is probably because:

<table>
<thead>
<tr>
<th>Agree</th>
<th>Undecided</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>One side does not have all the facts</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>They have different interpretations of the facts</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>They hold different moral values</td>
<td></td>
<td>26</td>
</tr>
<tr>
<td>They must bear in mind the need for support for their research</td>
<td></td>
<td>27</td>
</tr>
<tr>
<td>They are defending their own theories</td>
<td></td>
<td>28</td>
</tr>
</tbody>
</table>

Questions about Technology

Q 15. Technology is the application of scientific knowledge. | | 29 |
For each of the following statements please tick only the boxes which apply.

<table>
<thead>
<tr>
<th>Agree</th>
<th>Undecided</th>
<th>Disagree</th>
</tr>
</thead>
</table>

Q 26. In general women are reluctant to be scientists and technologists because of the way society has defined the role of women.

Questions about Values and Education

Values are a consequence of people's perceptions and beliefs. They are those things held to be of worth, and are used, often unconsciously, when making decisions. Values may be ideals such as justice, freedom, integrity or customs and institutions. They are closely linked with principles, ethics and morals.

Q 27. Social and value issues relating to technological development:

- should not be discussed in school at all
- are best discussed in science and technology lessons
- should be discussed in all areas of the curriculum

Q 28. Value issues only enter into technology when decisions are made about how it is to be used.

Q 29. If science teachers and technology teachers include discussion about social and value issues in their lessons, industry will be seen in more rational and realistic terms.

Q 30. If industry is seen in more rational and realistic terms, this may help to encourage young people into industry.

Q 31. Technology should be a part of all children's education from age 5 years.
Now please complete the questions below by filling in the blank spaces or by putting a tick at the side of the appropriate responses. You may tick more than one response.

Q 34. Personal details

Male [ ] Female [ ]

Age 20-29 [ ] 30-39 [ ] 40-49 [ ] 50-59 [ ] 60-69 [ ] 70+ [ ]

Q 35. I have a qualifications related to:

Science [ ] Physics [ ] Chemistry [ ] Biology [ ]
Technology [ ] Education [ ] Engineering [ ]
Other (Please State) [ ]

Q 36. I am actively involved in science or engineering research

Yes [ ]
No [ ]

Q 37. I am involved in teaching:

Science [ ] Science Education [ ] Technology [ ]
Technology Education [ ] Other (Please State) [ ]
Not involved in teaching [ ]

Q 38. I teach students aged:

5-12 years [ ] 12-16 years [ ] 16-19 years [ ]
Undergraduates [ ] Other (Please State) [ ]

If you are willing to take part in an interview for about 30 mins please give your name and a contact address and telephone number.

Name
Address
Telephone number

Thank you for completing this questionnaire. Please return the questionnaire to:
Anne Riggs, FREEPOST, Department of Educational Studies, University of Surrey Guildford GU2 5XH (sae enclosed)
Telephone 0483 300800 Ext 3165
January 1992

Dear Headteacher,

I am currently working for a PhD degree. Part of my thesis is concerned with understanding of science and technology and value issues. I am particularly interested in the views of people who are involved in science and technology education. During my research I will be seeking the views of science and technology teachers in schools and colleges; research scientists working in higher education who are involved in teaching undergraduate or postgraduate students, teacher trainers and providers of in-service training.

I would be grateful if you could give the enclosed questionnaires and covering letters to science or technology teachers in your school. All information will be treated as strictly confidential but I would be happy to provide a short summary of the findings of the research if you are interested.

Yours sincerely

Anne Riggs
(\textit{Ms})
\textbf{Lecturer in Science Education}

Encl
8th January 1992

Mr M C Pinchin
Education Officer
Education Department
County Hall
Kingston upon Thames
Surrey
KT1 2DJ

Dear Mr Pinchin,

I am currently working for a PhD degree. Part of my thesis is concerned with understanding of science and technology and value issues. I am particularly interested in the views of people who are involved in science and technology education. During my research I will be seeking the views of science and technology teachers in schools and colleges; research scientists working in higher education who are involved in teaching undergraduate or postgraduate students, teacher trainers and providers of in-service training.

I would be grateful for your permission to send copies of the enclosed questionnaire to a few teachers in some schools in Surrey. All information will be treated as strictly confidential but I would be happy to provide a short summary of the findings of the research if you are interested.

If you do not wish me to send the questionnaire please let me know before the end of January.

Yours sincerely

Anne Riggs (Ms)
Lecturer in Science Education

Ann Riggs

Anne Riggs (Ms)
Lecturer in Science Education

Encl
APPENDIX 8  RESULTS AND ANALYSIS

Questionnaire - version 1.

This questionnaire was handed to 16 people attending a course in January 1991. (see appendix for this questionnaire)

Responses to question 1

All respondents agreed with statements 1a and 1b.
1a. "Science is about observing and explaining the world."
1b. "Science involves discovering facts about the natural world."

All respondents disagreed with the following:
1c. "Science is the only way to explain the world we experience."
1e. "Science is difficult to understand, only the most intelligent people can understand science."
1g. "Scientists approach their work objectively, their feelings, wishes and personal attributes have nothing to do with the processes they carry out."

There were mixed responses to the following questions:
1h. - "Science deals in uncertainties, it offers the best explanation at the time" 43% agreed.
1i. "Scientific knowledge grows by accumulating facts." 86% agreed.

Summary replies to Question 1

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Not answered</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>6</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>b</td>
<td>6</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>c</td>
<td>0</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>d</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>e</td>
<td>0</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>f</td>
<td>2</td>
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<td>g</td>
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</tr>
<tr>
<td>h</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>i</td>
<td>6</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

A number of comments were written on the questionnaires such as:
In response to 1d - "Science is superior, prestigious knowledge". 86% disagreed with this

In response to 1g "They [scientists] think they do"; "Ideally yes, but all of these aspects will have an effect on coordinating research and interpretation of results." "Feelings take a back seat."
Responses to Question 2

This was an open ended question. In response to part 1 "What do you understand by the term ‘laws of science’", the responses were:

<table>
<thead>
<tr>
<th>Response</th>
<th>Number of people giving the response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laws</td>
<td></td>
</tr>
<tr>
<td>- as rules</td>
<td>4</td>
</tr>
<tr>
<td>- used for predicting</td>
<td>3</td>
</tr>
<tr>
<td>- explain observations</td>
<td>3</td>
</tr>
<tr>
<td>- constant</td>
<td>1</td>
</tr>
<tr>
<td>- not constant</td>
<td>3</td>
</tr>
</tbody>
</table>

Comments written in response to the question:

"Rules which work practically or fit within the present reality and known standards."

"Rules which appear to be constant."

"Rules on which other avenues of work are based."

"Generally accepted concepts usually specific to particular areas of science."

"Cause and effect relationship."

"All actions and happenings could be explained with authentic reasons ‘why it is so’."

"Attempts to explain. Attempts to enable predictions."

"Certain behaviour of materials can be predicted based on experience; and therefore appear to obey certain rules."

"Rules which go some way in explaining observations and knowledge at a particular time."

In response to Part 2 "Are such laws true? How can we assess the validity of the laws? Is there a distinction between validity and truth?" People replied:

<table>
<thead>
<tr>
<th>Number of people giving the response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laws</td>
</tr>
<tr>
<td>- are true, subject to further knowledge and investigation</td>
</tr>
<tr>
<td>- are accepted concepts</td>
</tr>
<tr>
<td>- validity can be assessed by evaluating laws/concepts</td>
</tr>
<tr>
<td>- valid with reference to circumstances</td>
</tr>
</tbody>
</table>

And written comments:

The laws are true not necessarily for long.
The validity of the laws work as long as it is practical / useful / truthful.

The truth is the 100% of validity. E.g. The concept of atomic structure and its usefulness for the application for the society.

The laws appear to be true based on the extent of our knowledge to date.

The validity of the laws can only be assessed by constantly evaluating them against knowledge.

The laws are ‘true ’ insofar as they fit the observed circumstances, they are valid or relevant for similar situations.

They are only ‘true’ in as much as we can understand the facts may be even more complicated but happens to fit the ‘laws’.

Yes, to a great extent. A narrow difference. Anything that can be proved straight away has validity (E.g. - acceleration due to gravity is the same on all objects) this would be valid. But when you say a stone thrown up in space never returns - it is a truth. Its validity cannot be proved in the classroom.

Laws true? - yes and no. Laws assessed as valid because they predict. If not true then not valid.

Sometimes yes given particular set of circumstances.

only true at a particular stage of our knowledge. They have to be modified in the light of new experiences.

Responses to question 3. People were asked to circle ‘agree’ or ‘disagree’ in response to: “Superstition has nothing to do with science”, “Astrology has nothing to do with science” and “In time we will have scientific explanations for everything including ESP [extra-sensory perception]”

<table>
<thead>
<tr>
<th></th>
<th>Agree</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>superstition</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>astrology</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>ESP</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

Written comments:
"To our civilisation there always would be so much to know to explain and that is rather larger to what we know / is proven."

"Many superstitions may be based on unexpected perhaps infrequent phenomena, that might be totally ‘bizarre’, leading to the acceptance of the superstition but subsequently explainable in the light of more recent scientific knowledge."

"Superstition has an affect on the way science is perceived some will accept there superstitions rather than science and colour judgement (affect observations?). Astrology tries to fit personality etc.to a pseudo-scientific type of study. Astrology is based on the planetary movements. Gravity does affect individuals. So it can be true.

A61
ESP - could prove to be related to vibrations travelling!!"

"As we find out more, so we realise there is more that our knowledge and that time cannot explain."

"Some superstitions may have a grain of truth in them. Astrology involves knowledge of the constellations although how this knowledge is interpreted and applied is non-scientific. " In time" - eventually, at some far, far distant time."

Responses to question 4 "Can you explain the role of refutation in experimentation?" was not understood by many respondents. People commented thus:

"Einstein theory of special relativity meant that Newton’s laws were wrong. But Newton’s laws still work when you consider "normal" daily events e.g. cars crashing, picking up things etc."

"The results of an experiment can be refuted on the basis of their validity and difference if any, in results under slightly different conditions - which aren’t really related to the experiment. Arranging elements in Periodic table basing on atomic mass - etc. etc. was refuted which let to proper arrangement."

"Possibly not total rejection but modification and adaptation."

Responses to question 5

Respondents were asked if they agreed with any of the statements.

5i. "Science is concerned with logic and proof, by logical reasoning true statements can be deducted."

Three people commented: "but there's more to it than only logic" and "this is near to the truth but there are a unique unrepeatable events."

5ii. "By repeated investigation and observation of phenomena, the cause or effect of the phenomena can be found. The explanations of phenomena are then used to formulate laws and theories."

5iii. "Scientists are reluctant to embrace new theories and explanations, rather they try to argue away observations which do not fit the established views." Two people commented:

"They shouldn't be reluctant to do so but it is tempting to stick to the status quo, and defend a pet theory or established law. Truly 'scientific' scientists would be open minded about new ideas and some probably are."

"Scientists like to embrace new theories but do require considerable and independent results to change a currently held view."

A summary of the responses to question 5:

<table>
<thead>
<tr>
<th>Statement</th>
<th>agree</th>
<th>not answered</th>
<th>partially</th>
</tr>
</thead>
<tbody>
<tr>
<td>science as logic and proof</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>science is repeated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>investigation and observation</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>reluctant for new theories</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
Responses to question 6
This was an open-ended question which asked respondents to explain what they understand by hypotheses and theories. People responded thus:

**Hypotheses**:
- an idea to explain an observation.
- is a theory based on best explanation of results/situation but cannot yet be proved.
- comes from the experiment.
- is an accepted theory, considered to be 100% true but proof is not available e.g. Avagadros
- an idea which seems to fit and can be tested in order to draw up a theory.
- suggesting a result prior to testing
- hypotheses are to do with speculating.

Examples of hypotheses:
- base metals can be changed in to gold
- Avagadros
- the earth is sucking the objects from the space and the surface.

**Theories**:
- an idea based on the results of experiments and observations to test earlier hypotheses.
- the "best" explanation at the time.
- is a formulated idea - can lead to hypothesis
- the particular hypothesis may lead to the theory.

Examples of theories:
- relativity
- gravitation

Responding to the question "How are hypotheses and theories relevant in the scientific process?" People wrote:
- basis of scientific investigation.
- hypothesis -> experiment -> observations -> inferences -> theory -> more experiments and observations -> "law" or modified theory.
- most scientific discoveries were made from hypotheses and theories.

Responses to question 7
This question included a number of statements: "Do you ever try to discuss the nature of science with your pupils" "Do you ever discuss the nature of science with friends/acquaintances" and "Have you any thoughts about how non-scientist friends and acquaintances view the work you do as a scientist or science educator?" People were asked to circle the appropriate response:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Yes</th>
<th>No</th>
<th>Not Answered</th>
</tr>
</thead>
<tbody>
<tr>
<td>discuss nature of science</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>with students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with friends</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Asked how they thought non-scientists see science people commented:
"They think it is very difficult (said by 2 people)
"They find it very off-putting I think."
"Conversation stopper - you must be so clever!"
"Very technical knowledge required before they can take part in any discussion."
"We are all scientists and educators the difficulty is persuading everybody."
"Many would like to enlighten themselves."
"Try to encourage them to see science as a investigative subject not simply learning facts."

Responses to question 8

The question: "What do you understand by the term metaphysics", was not well answered 71% said they did not understand the term. Others replied:
- philosophical ideas about science and its meaning.
- philosophical view of science

Responses to question 9

The question 9 asked people to "explain the following words" and try to identify and distinguish between them

a) Imagination:
- using mental processes with experience
- lateral thought, creativity
- baseless
- allowing one's mind to construct a series of circumstances e.g. story
- lateral thinking, development of ideas.
- trying to put oneself into the situation

b) Intuition
- similar to imagination but involving a sudden leap into the dark
- instinct based on experience
- there is a basis
- feeling something or 'fact' is right
- gut feelings possibly not based on specific knowledge
- using one's experience

c) Luck
- random, chance occurrence
- pure chance unpredictable
- purely by chance
- chance discovery of a favourable situation
- fortuitous circumstances which are recognised and put to good use.
- can stimulate the open mind and lead to a discovery/solving

In response to the question "How important do you see these three in scientific work?" all the respondents said that these were important in investigative work.
May 1992

Dear

I hope you remember filling in a questionnaire for me and kindly offering to be interviewed. I would like to visit you to carry out a 30 - 45 min interview at a date and time which is convenient for you. Please indicate which of the following days would be suitable along with a suggested time. Please tick as many days as possible.

Thursday 4th June
Monday 8th June
Tuesday 9th June
Friday 12th June
Monday 15th June
Wednesday 17th June
Wednesday 24th June
Thursday 25th June
Friday 26th June
Monday 29th June
Tuesday 30th June
Wednesday 1st July
Friday 3rd July
Monday 6th July
Tuesday 7th July

Thank you once again for your help.

Yours sincerely

Anne Riggs (Ms)
Lecturer in Science Education

Head of Department
Professor D E James

Department of Educational Studies
University of Surrey
Guildford
Surrey GU2 5XH
England

Telephone: (0483) 300800
Fax: (0483) 300805
Telex: 859831
18 March 1992

Dear

Thank you for returning my questionnaire and for the offer to interview you. I have been quite overwhelmed by the response - 70 people have offered themselves for interview. I was expecting about 20 offers. As you can imagine I now need to decide how many people I can interview and select who should be interviewed. This can only be done after I have analysed the data.

May I therefore thank you once again and say that I may perhaps contact you again in the near future.

Yours sincerely

Anne Riggs (Ms)
Lecturer in Science Education

Head of Department
Professor D E James

Department of Educational Studies
University of Surrey
Guildford
Surrey GU2 5XH
England

Telephone: (0483) 300800
Fax: (0483) 300803
Telex: 859331
APPENDIX 11. ANALYSIS OF THE FINAL VERSION OF THE QUESTIONNAIRE

Respondents to the questionnaire personal details:

Male = 108  Female = 90  Total = 211

Ages: 30 people aged 20-29yrs  41 people aged 30-39yrs
     87 people aged 40-49yrs  23 people aged 50-59yrs
     6 people aged 60-69yrs  1 person aged 70+

23 people did not answer

Qualifications

62 people with science qualification
54 people with physics qualifications
62 people with chemistry qualifications
57 people with biology qualifications
34 people with technology qualifications
122 people with education qualifications
16 people with engineering qualifications

28 people involved in research

Areas taught
111 people teaching science
48 people teaching science education
73 people teaching technology
40 people teaching technology education

Age of students

70 teaching students 5-12 yrs
71 teaching students 12-16 yrs
50 teaching students 16-19 yrs
31 teaching Undergraduates
10 not involved in teaching
ANALYSIS OF THE FINAL QUESTIONNAIRE

Three frequency counts were carried out using SPSSX. The first in early April 1992 included 160 returns questionnaires. The final count (on 211) took place in October 1992. These results are given in the appendix. It can be seen from the figures that there is little difference between the three frequency counts.

8.2.2. Responses to statements:

Comments which were written on the questionnaire are included when they are indicating something different from the overall finding. These are coded A.

Statements about the format of the statement and the means of responding are coded B.

Question 1.

Given sufficient time, science will be able to explain all known phenomena.

% Agree Undec Disagr

Given sufficient time, science will be able 24 19 57
to explain all known phenomena.

Q 2. Many scientific models (such as the model of the atom or of DNA) are duplicates of reality.

A "A model is a model". "Models are representations of reality, not reality itself." "not duplicates, but certainly very good representations"

B This was one of the most ambiguous questions with 14 comments about the ambiguity.

Q 3. Scientists are not really influenced by politics because they work in particular institutions and are pretty much isolated from society.

A One person thought this influence was recent and that influence was less when laboratories were smaller. Another commented:
"Clearly the topics they work on are determined by external factors including politics but it is less clear about [how] the actual scientific findings are influenced."

Q 4 When scientists carry out investigations correctly they discover facts that will not change in future years.

B As expected the word 'facts' caused problems. Four people said in writing that they were unhappy about the word: "Define facts". "The answer is no because scientists do not discover facts."
Q 5. Scientists should be concerned with the potential effects (both helpful and harmful) that might result from their discoveries.

Q 6. Men have influenced the way science is done so that it is primarily a masculine activity.

B Two people thought that the question should have been in two part - part 1 = men have influenced the way science is done answer - yes, part 2 = so that it is primarily a masculine activity - answer no.

Q 7. The government should give scientists research money to explore the unknowns of nature and the universe.

Q 8. Science is different from other areas of human thought.
A "Agree if different from equals distinct". If it weren't how would we perceive it?

Q 9. Science is concerned with discovering the laws of the universe.

B This question was considered to be ambiguous by one person and impossible to answer by another.

Q 10. Science tries to explain observations about the universe.

B One person considered this question impossible to answer.

Q 11. Science is the most adequately tested medium of explanation.
A Comment "but only in the areas with which it can properly deal".

B One person considered this question impossible to answer.

Q 12. Science is concerned with making precise measurements.

B One person considered this question impossible to answer.

Question 13.16 Scientists are concerned with observing and explaining their observations.
Question 13.17 Scientists produce explanations for events and then they carry out experiments to support their explanations.

Question 13.18 Scientists produce explanations for events and then they carry out experiments to try to disprove their explanation.

Question 13.19 Scientists carry out observations, collect data and develop hypotheses which they then attempt to prove.

A One person said the first part of this question was true but the second half was false.

B As expected the word 'prove' caused problems, three people commented in this.

Question 13.20 Scientists are concerned with finding the truth.

B As expected the word 'truth' caused problems, two people commented on this.

Question 13.21 Scientists choose their area of work because of the possible benefits of their work for the society.

A One comment: "increasingly as this coincides with financial reward."

Question 13.22 Scientists are flexible and adaptable in the way they work and are willing to try many different methods.

Question 13.23 Scientists work by instinct and intuition.

Question 14.24 When scientists disagree about a scientific matter it is probably because one side does not have all the facts.

Question 14.25 When scientists disagree about a scientific matter it is probably because they have different interpretations of the facts.

Question 14.26 When scientists disagree about a scientific matter it is probably because they hold different moral values.
Question 14.27 When scientists disagree about a scientific matter it is probably because they must bear in mind the need for support for their research.

Question 14.28 When scientists disagree about a scientific matter it is probably because they are defending their own theories.

A General comments: "They can be a bit stupid sometimes"; "This section is impossible." "There is some truth in all these. It is because rarely is the phenomenon capable of being specified by experiment so it is open to uncertainty."

B One person considered all of this question was impossible to answer.

Questions about Technology

Question 15. Technology is the application of scientific knowledge.

Question 16. Technology is mainly concerned with making and selling goods.

Question 17. Technology is about finding appropriate solutions to human problems.

A One comment technology is about "improving the quality of life - weapons etc excepted."

Question 18. Technology enables us to control our environment

Question 19. Many social problems like poverty, crime and unemployment are the result of scientific and technology developments.

Question 20. We will solve our current environmental problems by the use of new technologies.

Question 21. Few people have a clear understanding of how many of the goods they buy are made.

Question 22. In order to improve the quality of life, it would be better to invest money in technological research rather than scientific research.

A Written response pointed to the need for both because: "you cannot separate these two
researches".

B One person considered this question very simplistic.

Question 23. Do you think that scientists and technologists should be given the authority to make decisions about a) the development of genetic engineering?
   b) the use of genetic engineering techniques?

   \[ \text{Question 23. Do you think that scientists and technologists should be given the authority to make decisions about b) the use of genetic engineering techniques?} \]
   \[ 23b) 16 \ 19 \ 66 \]

Question 24. Science and technology could offer a great deal of help in resolving social problems like poverty, crime and unemployment.

Question 25. In general women and men have the same intellectual abilities which means they are both equally able to be scientists and technologists.

Question 26. In general women are reluctant to be scientists and technologists because of the way society has defined the role of women.

A Comments: "or because of the way society has defined science and technology"; "they are reluctant - otherwise there would be more of them - but the reason is debatable"; "agree though this is not in my view the only reason." "Women may also in some sense, be to right to reject science as it is practised." "No women are not to be ashamed of wanting different things than men do, lots of them do." "Nothing to do with science and technology -, no such thing as masculine science see Q 6"

Questions about Values and Education

Question 27.42 Social and value issues relating to technological developments should not be discussed in school at all.

Question 27.43 Social and value issues relating to technological developments are best discussed in science and technology lessons.

Question 27.44 Social and value issues relating to technological developments should be discussed in all areas of the curriculum.

Question 28. Value issues only enter into technology when decisions are made about how it is to be used.
Question 29. If science teachers and technology teachers include discussion about social and value issues in their lessons, industry will be seen in more rational and realistic terms.

Question 30. If industry is seen in more rational and realistic terms, this may help to encourage young people into industry.

Question 31. Technology should be a part of all children's education from age 5 years.

Question 32.49 Decisions about whether nuclear energy is used to produce electricity are made by elected representatives and civil servants.

Question 32.50 Decisions about whether nuclear energy is used to produce electricity are made by Philosophers, theologians and other academics.

Question 32.51 Decisions about whether nuclear energy is used to produce electricity are made by Industrialists

Question 32.52 Decisions about whether nuclear energy is used to produce electricity are made by the public.

Question 32.53 Decisions about whether nuclear energy is used to produce electricity are made by Scientists and engineers.

Question 33.54 The people who should make decisions about whether nuclear energy is to be used to produce electricity are Elected representatives and civil servants.

Question 33.55 The people who should make decisions about whether nuclear energy is to be used to produce electricity are Philosophers, theologians and other academics.
Question 33.56  The people who should make decisions about whether nuclear energy is to be used to produce electricity are Industrialists.  

Question 33.57  The people who should make decisions about whether nuclear energy is to be used to produce electricity are the public.  

Question 33.58  The people who should make decisions about whether nuclear energy is to be used to produce electricity are Scientists and engineers.  

A Comments; "everybody should have a say"; "the questions seem to indicate only one of the answers should be agreed with and the groups aren’t mutually exclusive, are we supposed to be dealing with stereotypes here?"; "everyone has a right to express a view"; "What does make decisions mean? Does it mean hold a view, or "be in a position to implement your view?"  "Perhaps we should ask whether the elected representatives and civil servants should have a relevant scientific background to understand and weigh the ‘facts’ in order to make a considered judgement.”  "No" added and emphasised.  

"The problem in this - as in so many other areas - is that those actually making decisions do so, far too often, in response to single-issue pressure groups, rather than after systematic consideration of all the implications and risks".  "They all have a valid say".
APPENDIX 12

Table 1

<table>
<thead>
<tr>
<th>Respondents</th>
<th>Technology is the application of scientific knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percentage Agreeing</td>
</tr>
<tr>
<td>Biologists</td>
<td>88</td>
</tr>
<tr>
<td>Non Biologists</td>
<td>67</td>
</tr>
<tr>
<td>Researchers</td>
<td>93</td>
</tr>
<tr>
<td>Non Researchers</td>
<td>68</td>
</tr>
<tr>
<td>Science teachers</td>
<td>83</td>
</tr>
<tr>
<td>Other teachers</td>
<td>61</td>
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DF = 1

Table 2

<table>
<thead>
<tr>
<th>Statement</th>
<th>Percentage agreeing %</th>
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</thead>
<tbody>
<tr>
<td>Technology enables us to control our environment</td>
<td>82 Technologists 58 Other</td>
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Chi square = 6.9, Signif = 0.008, DF = 1

Table 3

We will solve our current environmental problems by the use of new technologies.

<table>
<thead>
<tr>
<th></th>
<th>Percentage agreeing %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physicists</td>
<td>14</td>
</tr>
<tr>
<td>Others</td>
<td>28</td>
</tr>
</tbody>
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Chi square = 4, Signif = 0.04, DF = 1
### Table 4

<table>
<thead>
<tr>
<th>Science is different from other areas of human thought</th>
<th>Percentage agreeing %</th>
<th>Chi Square</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physicists</td>
<td>38</td>
<td>4.9</td>
<td>0.03</td>
</tr>
<tr>
<td>Others</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science Teachers</td>
<td>35</td>
<td>8.4</td>
<td>0.003</td>
</tr>
<tr>
<td>Other Teachers</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>34</td>
<td>4.5</td>
<td>0.03</td>
</tr>
<tr>
<td>Women</td>
<td>20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DF = 1

### Table 5

<table>
<thead>
<tr>
<th>Science is the most adequately tested medium of explanation.</th>
<th>Percentage agreeing %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Others</td>
<td>31</td>
</tr>
<tr>
<td>Science teachers</td>
<td>47</td>
</tr>
</tbody>
</table>

Chi Square = 5.1, Signif = 0.023, DF = 1

### Table 6

<table>
<thead>
<tr>
<th>Scientists work by instinct and intuition.</th>
<th>Percentage agreeing %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researchers</td>
<td>64</td>
</tr>
<tr>
<td>Non-researchers</td>
<td>33</td>
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</tbody>
</table>

Chi Square = 9.3, Signif = 0.003, DF = 1
Table 7

<table>
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<tr>
<th>Technology should be part of all children's education</th>
<th>Percentage Agreeing %</th>
<th>Chi Square</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Teachers</td>
<td>93</td>
<td>7.9</td>
<td>0.005</td>
</tr>
<tr>
<td>Other Teachers</td>
<td>78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>79</td>
<td>7.8</td>
<td>0.005</td>
</tr>
<tr>
<td>Women</td>
<td>93</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DF = 1

Table 8

<table>
<thead>
<tr>
<th>In general women are reluctant to be scientists because of the way society has defined the role of women</th>
<th>Percentage agreeing %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researchers</td>
<td>37</td>
</tr>
<tr>
<td>Non-researchers</td>
<td>64</td>
</tr>
</tbody>
</table>

Chi Square = 7, Signif = 0.008, DF = 1
8.3 Interviews

8.3.1 Personal details of Interviewees

Male = 15  Female = 12

Biologists = 4  all female
Chemists = 7  male = 4  female 3
Physicists = 9  male = 6  female = 3
Technology teachers = 5  male = 4  female = 1
General science = 2

University engineers = 4  male = 3  female = 1
Research scientists = 3  all male

Primary school teachers = 2
Secondary school teachers (may also teach sixth form) = 10
Sixth form teachers = 2
Science or technology educators working in higher education = 7
University teachers = 3
APPENDIX 14

ANALYSIS OF INTERVIEW TRANSCRIPTS

A79
What is science?

It is about trying to find answers, trying to find patterns and how things work with the intention being that having learnt the patterns, learnt those lessons by experiment, essentially we should be able to do things we couldn't do before.

Is science different from other areas of knowledge?

I don't think scientific knowledge is any different from other areas, there is a difference perhaps in scientific method, but then I don't think it is exclusive to science. It's a what you call progressive, often assumed to be linear type approach to finding things out. It is just as valid as history, historical research as it is in a scientific experiment.

There are a number of words that were problematical. Two are facts and proof. Can you tell me what your picture is about scientific facts?

I'm not sure what facts are. Facts are things people think they have proved. Somebody's fact is often someone else's opinion. You only have to look at the court cases recently where so called scientists were accused of producing facts which subsequently we come back and say well actually those facts weren't facts. Someone had asked the wrong question, they had the right answer to the wrong question and drawn the conclusion from the data they had been given, what they had been asked to do, and a different view at a different time with different data put a question on that.

So how do you find out what questions to ask? Not just with reference to forensic science.

All the time you are trying to move to a greater understanding but what that means at one time in history is conditioned by the other things around you. Things like who pays.

In identifying the questions to be asked, is it about searching to extend our knowledge, is this pure science? When you introduce thoughts like who pays are you introducing another aspect?

At the end of the day somebody pays for anyone to do experiments, to be a scientist. Whether that makes all science applied or pure I don't know. I have real problems with these terms, there is still a payer. If someone is challenged to do some research and they are not to have an outcome that's got any real value, then perhaps they are defining where they are going as much as someone who says they want to build a bigger rocket. I don't know that the things are any different. I don't know whether for instance...was Faraday doing pure research or was he doing applied research? He was discovering the essence of electricity and making predictions about the future when he was doing that and that was encouraging him to move on. He, with Davy was allowed through France by Napoleon when we were at war with France. In those days science was seen as separate from politics and separate from war. And yet de vinci was making his money out of building war machines. It's all depends on how people are looking at it at the time.
Can I refer you to the question about scientists being influenced by external factors such as politics.

I think we cannot separate ourselves from the world who ever we are. I think there is a real problem if someone is paying your salary whoever they are, then people will do what they need to do to continue to earn their living. They will give the answers people are looking for. In the forensic science service it is supposed to be about facts and it is not, it appears to have been in the last twenty or thirty years but it hasn’t been about that at all. It has been about proving the prosecution case because they are employed by the prosecution.

Can I just check on that? There are two things about this influence aren’t there? There is one to do with the choice of topic you look at and the way you can do that, something about the whole methodology and there is another about the findings. Are you saying the influence is there in both cases?

Yes, if I wanted to be a scientist someone would have to pay me in some way to go and do that. I would have to make a case to go and do something. The choice of the area is influenced by the political pressure and having gained that funding people are going to be asking questions about whether I am doing what I set out to do.

Suppose you come up with something which was potentially not what they wanted. Would this influence the way you report your findings?

No I don’t think those people lie, I just think they didn’t look in certain areas( referring to forensic again). It was probably a case of simple controls and missing certain variables. So they come up with positive tests, they do not look to see if they test is only going to work on that subject. They didn’t lie in their conclusions but they didn’t run down certain tracks because they thought they knew where they were going.

Would this apply in other situations?

Yes, this is just an example.

I want to explore this problem of what questions to look for in science. What of science and technology education in schools? Somewhere in this is how technology relates to science and applied science. Many respondents said that technology was applied science. Where are you in this?

I suppose simplistically technology is about solving real problems, it is almost defined in these terms in the NC document; finding something we can do and do it better. To do that you need to understand the things you are using when you are doing it. One of the bodies of knowledge is science, you can’t design cars without understanding Newton’s laws of motion. I don’t know what applied science is if it isn’t technology. But I don’t think technology is exclusively applied science.

What about the science we teach in school?

Often it is history. I don’t know if we are teaching children to be scientists or teaching
them to use the scientific method but we are perhaps moving in that direction. There has been too much of what people call science which was hurling sets of facts at people with no scientific method. "You have just drawn the wrong conclusion Johnny, it should have been a straight line." Johnny's wasn't. If he is to be a real scientist he has to handle the facts, the shape of his line on his graph and not be told this is the answer. There is this tension between right answers and the right approach. It would be daft to expect him in forty minutes to discover Hooke's law.

Where does applied science or technology fit in this.

I don't think it is in there, even the technology bit. One of the things we ought to be doing is blurring the edges. I think primary schools have got it right. They teach pupils, secondary schools teach subjects. When people leave they turn back into people again. There is a problem in there of approach, we have these isolated bits sitting around the school often, yes we have cross-curricular links and things but it is often nobody's job. Science and technology departments are busy and are often at different ends of the school, they can't relate. I don't know whether electronics is science or technology. It is a bit of both. You can't solve many technological problems without going through the scientific process. The whole business of design is in the technological sense not just the aesthetic bits but the experimental process of using a scientific method to decide whether this is or is not a better solution. They are not separate, they are the same thing.

You talk about a scientific method, is there such a thing? What is it?

It is the business of trying to move towards things you can perhaps call facts. The idea that a systematic approach to taking measurements and comparing those and looking at what's fixed and what is variable in there and controlling variables, the whole business of doing all of that is what is science.

One question asks about men influencing science. Have you any comments about this?

It is probably no different from other major areas of study in the world. Even in things as female as birth men have influenced the design of the equipment. If that is science, I don't know. Men historically have been in the positions of power, it is not just restricted to science.

Why are there so few women in science?

Again it is not just in science. We have the stereotyping in hospitals when we talk about doctors we think of men and nurses we think of women. Observation seems to show to me that where things are to do with the helping of people, where people can see the connection, women are more likely to be in that area than things which are seen as separate so if you market engineering and science as things to do with weird equations and power stations then you are not attracting the women. But if you were to sell it as the production of electricity which is of use to the human race then I think we would change it. The big institutions, certainly the Engineering Council are stacked full of old men who still think that a women's place is somewhere other than there. That is going to be a long slow job. We change the pictures but we don't actually change the messages.
I have this understanding of these old men influencing the science and engineering. Are you saying that the next set of old men who are our present scientists and engineers will be different?

Not a lot, a bit different. I think you probably have to go several generations of men/people. The crazy thing about engineering is that they are far more concerned about one institution as opposed to another institution than they are about the business of engineering. Most of them can't see that they have far more in common than have differences. They are hung up the mechanical, electrical or civil - we don't get dirty, we work in labs. So there is still all that going on. Until they stop that infighting and start looking at the business of engineering nothing will come out of it.

Is this lack of communication/cooperation something which is peculiar to engineers? Or is it something typical of men or what?

We still have a society which expects men to go out and earn a crust and go out and earn a bigger crust. We don't have a society overall which expects women to do the same thing. The whole career game and the status bit and all the rest is all tangled up in that.

The questions about discovering the laws of the universe and observing and explaining the universe. Can you explain any differences?

If we could explain sufficient observations we could discover some pattern or non-pattern in those observations and that is in general what we call laws. So they are tangled together. You couldn’t have any laws, we couldn’t explain if we didn’t observe. Put the other way round we could not get to writing the laws if we didn’t observe.

Writing the laws, does this imply they are not there to be discovered?

The laws are all models, Newton’s laws of motion are not in a sense reality, the have been discovered by observing the way things move that we can get to positions where we can predict if we make certain assumptions about the way things behave. That made sense until Einstein came along but when driving about in a car Newton’s laws have far more to do with it than Einstein’s. The observations led us to find some patterns in the behaviour of things and those patterns when we commit them to some set of words or equations are what we call laws.

Can we explore meanings of technology and what it is about? You talk of technology as being about solving problems. There are a few things around that, one is the relationship between this activity and our surroundings, the environment and the question which says that values issues only come in when you decide how to use the technology.

When you look at the nuclear thing, the main thrust in nuclear research was, if I have got my history right, during the war. It was explored because it was seen as a means of answering problems relating to war - back to this status thing. Having got people who were doing this kind of thing for a living they had an interest in doing this kind of thing and still do. there was a possibility of turning that research into peaceful purpose of having power stations based on the findings. And we have chosen not to run down that track as
perhaps we might have done or to run too fast down that track. In all of that you have value judgements which do not just drive what you did with it but are part of starting that work in the first place. Value judgements come all the way through because you are planning all the way through. In general nowadays we stumble across these things, we do not set out looking for something, we might find what we are looking for but we might find something else which is related to it which sets you looking based on somebody’s own judgement as to whether that was worth looking for. At the moment we don’t choose to look for ways to feed people, we could but we choose not to. We still choose to invest huge amounts of money, although declining, on bigger and better chunks of metal and chemicals to hurl at each other. That is all loaded with value judgements.

How clear is it to teachers and others that value judgements are involved?

It is not clear at all. In science education we push out facts, concrete outcomes.

Different responses about who should make decisions about nuclear power and genetic engineering. Do you see any difference?

If we muck it up both have the potential to cause complete chaos. If we get it right both have potential to make life better. What we can’t have is people in ignorance making decisions. Who that means has to make it I don’t know. Politicians are people elected by us as a society to make decisions, if we don’t like the decisions we don’t elect them. We don’t elect the scientists. The scientists are often employed by the politicians indirectly. The scientists need to be the advisers. In a sense it is no different if politicians do it or Joe public does it. One is a representative of the other. Scientists have a vested interest in continuing what they are doing. The answer is always going to be yes.

You are not then seeing any particular differences between the two contexts.

No.

Are there any differences between school technology and technology in the wider world?

There shouldn’t be. The technology outside is essentially based on business, people are doing things which someone is going to pay them to do. The children should be dealing with real things that really need doing. There is no cash transfer going on there but essentially we are trying to meet a perceived need. One of the problems at the moment is that most of the children are not engaged in that process at all, they are still doing a need they haven’t perceived. They are several stages removed from the need. School technology will have got it wrong if the processes going on there, the business of how we find out what the need is, how we begin to address that is different conceptually from what is going on in the wider world. It will have missed its target.

Engineering and technology, any differences?

No but engineers would argue that there are differences. No.

The role of intuition and instinct in science.
There is a danger in science in thinking that because we can’t see an explanation we don’t believe it happens, the intuition bit is the conceptual link. The creative aspects of science - you get to that but you are not actually doing science you are doing something else. The great scientists who made the great leaps forward took two ideas and spotted some connection between them and created a third idea. And they do that often as a leap of faith, they actually believed in some connection and then set out to prove it was there rather than proving it was there by their experiments. The great scientists have results that help their case. E.g the ‘discovery’ of the electron, Newton under the apple tree. These are mighty, non-logical thoughts. The logic comes in trying to explain to everyone else why you think that is the case. There is a spark.

Can this be nurtured?

No I think because most of what we do is about looking for right answers, come up with the answers in the book, we discourage it. I suspect that primary schools encourage it more than secondary schools. That is one reason why kids are more of a pain in secondary school than they are in primary because the bits of them which are their contributions to the process is stifled. We still write exam papers which demand right answers/demand knowledge rather than application.

In your teaching would you consciously include values awareness in certain topics/all topics you were teaching?

You are really aware, conscious of the time. In areas like sex education yes. We did the mechanical bits and that’s all. It requires appropriate sensitivity to the people and not just to the body of knowledge. In daft things like power cables, surface versus underground, the size of the cables there are decisions about which do you want? The syllabuses in general don’t encourage discussion because science is seen to be about rights and wrongs. You can’t have a question to which you don’t know the answer.

Is it changing?

Slowly. If we looked back to exam papers 10 years ago we would probably find quite dramatic changes.

What about industrial awareness in all this?

Children more and more in the last few years have been asked to look at issues of values and then start asking the questions and I think that is good.

Is this something industry is keen to promote?

In general yes.

If there is more discussion of value judgements, will industry be seen a more positive and realistic image?

A85
The great discussions of the moment are in relation to environmental bits and companies are making statements internally about their so-called consideration for the environment. You can't change overnight but I think that more and more people are realising that if you are going to refine oil you are going to have waste products and you have to move things around in great quantities. They start looking at those issues instead of seeing just some kind of chemical product.
INTERVIEWS 13 and 14 Female Home Economics teacher (R) and Male CDT (M) (fhet) (mcdtt)

What is science?

M We are not science teachers, at least I am not and I don't think R is, therefore we do not approach things in the way science teachers do.

How do you see the difference between science and technology?

M Technology is to do with improving the quality of life for people - we want our kids to see that and when they are making decisions in project work I try to steer them towards projects which are about improving the lot of other people like machines, equipment technology for the informed and handicapped.

Do you spell out the reasons why you steer them this way?

M No I don't

Is it negotiated?

M Yes because a student is free to choose. I try to get pupils to try to serve the needs of others rather than look to themselves e.g making toys for real children, they go to play groups, courtesy of R and her colleagues. This could be seen as a model of the industrial milieu where the designers asks the punters what they want and deliver it. I see it in terms of doing something for small children. What we don't do and what we should do is give those toys away.

R. - I think we would have risks with this - they are not safe enough, the children evaluate this, and the pupils like to have them.

Can I ask you individually about the value judgements which are being brought? What about social issues, do you encourage children to think about where the material comes from when they are choosing which material to use? Do value judgements come into your technology?

R. - Not in our projects, but the whole process is based on their value judgements.

Do you encourage them to make these explicit?

M - in presenting ideas about what they will do or not do, they have to say in their folder why. A sophisticated child will say a lot of things at once, you would have to unpick it. We have too much to do to consciously attempt to address the wider social issues. We should do, we have done a major curriculum audit on PSE for example and particularly sex, drugs and violence.

Has technology been brought into this?

M I don't see sex drugs and violence as being part of our remit.
R How do you mean?

M I was thinking about the impact of technology.

R - I don't think either of us are qualified to speak about that.

M - You could if you wanted but when I did it on behalf of the faculty it was rejected. Our remit is National Curriculum technology.

R I think you question was how much is technology incorporated in PSE.

Not quite, for example in talking about drugs in PSE we could include discussions on why are drugs produced, how are they marketed, how used?

R - this is not included that I am aware of.

Within technology do you talk about these issues eg production of new foods - why they were produced and the implications for communities and different cultures.

R - We do a lot of that with the sixth form there is a lot of this in the A level syllabus but not at other levels.

How do you deal with AT4?

M - There is a lack of clarity about the present orders, they are extraordinarily complex and unclear. The committee itself could scarcely agree, different members of the committee went off with different interpretations about what had been agreed on and the net result is that schools have been interpreting the orders in many and any ways. We are now at the end of our trial for year 9 i.e. we are a year ahead of ourselves. Among the other precepts which I brought to bear were, in fact we would go for quality, they would work in resilient materials, graphics, textiles and food, they would do projects which had depth, balance and relevance etc, they would take as long as it took to do that well and the emphasis was above all on the skills that we the staff had. There would be no deskilling of staff, we might pick up other skills along the way i.e. now I am capable of making tea - just, R is fairly useful in the workshops and so on, but I would not presume to hold a lesson here (HE room) and vice versa, but we have modest overlap. All these precepts I have applied to managing the work that we do. What the Engineering Council and others have been railing about is the Blue Peter approach - making Stonehenge from toilet rolls - this is not technology. But the government itself has a very muddled perception of technology, because they are products of liberal education, they don't know their arses from their elbows. They rely on advice and if the advice is unclear or has been hijacked, the net result is there is a great deal of confusion. My understanding is that what they wanted was that kids would actually learn how to work with all these materials as before but with much increased intellectual rigour.

We therefore spend most of our teaching time where kids are using hands on and written work and theory work is done at home. So AT4 is not really what we are about. They are evaluating what they have done, how well it works and can they make it go better next time.
R - In HE/FT we have AT4 incorporated briefly in years 8 and 9 in two areas, in the toy projects, play project. They interview old people about the toys they had in the past. In our energy project we are looking at traditional equipment versus modern. These are the only references to AT4 we make.

M - Given the muddle over the orders I have sort to thread a way through so that we are protected from the Secretaries of State. So far it has worked because we have stuck to the POS. We are now waiting for the SATs. We are not thinking in terms of ATs 1-4

Can I ask you individually what technology is?

M - It is improving the quality of people's lives.

R - I agree with M on that. It is about facilitating making things easier, going from the horse to the tractor.

Where is science in this?

R - Integral, I sometimes wonder how you can separate the two.

M - Technology is not the appliance of science. It is in fact using scientific theories, laws, phenomena that have been worked through from pure, applied science. But the focus of the entire exercise is ...

R - But M if you look at heat transfer is that science or technology?

M - It depends how it is used.

R - The two are fused.

M - Yes the acquisition of basic scientific knowledge is incredibly useful and necessary for technology, and technology is not going to go a long way without that scientific input but technology is also drawing upon maths, arts, traditional crafts etc. It becomes in fact a melting pot for all these and science is but part of it.

What is science then?

M - Science is essentially the hows and the hows and the whys. If we are going to talk about how the body converts energy there is a lot of laws that apply. The matter of particle physics....

R - The example you have given has to be much more scientific than technological.

M - No I stand by that. If you are looking at how the body works that is more scientific and without that basic knowledge you are not going to go a lot further in discussions about how you can improve diet or health you need that background scientific knowledge. That has to be your starting point, you have to know about saturated and unsaturated fats etc.
Have you talked with science colleagues? I am wondering how much technology goes on in science.

M - What was originally our thing has been hijacked by many other areas so now the kids are always into this. They do not know necessarily that we were always into this long, long before the others. This does not matter in a way except that other people now it as a way of solving their curriculum problems. The problem is a lot of people are unable to differentiate between problem solving persay and solving a problem when information has to be gathered. 'How can we build a tall tower using two copies of the Guardian is often cited as a wonderful solution. Science people do that but there is no input of information, there is no research required or synthesis of ideas, no grubbing around trying to get to the bottom of the problem. Solving a problem is not of itself any great worth unless it leads to some specific purpose and it has some intellectual rigour applied to it. When the science dept. does move from chalk and talk tends to be a sudden burst of potatoes and cocktail sticks. "Let's make a bridge guys." There is no notion of compression and tension, stability of structures. It is unpicking the bowel system, examining how magnets work, so much is done in vacuo. Much of what we do albeit in fairly loose conversation with them because in principle we should be working closely but time precludes it, much of what we do it applying quite literally some of the theories they have been plodding away at. Eg when 3rd years make a buggy it is the most enormous problem. They have done all that in science in principle, but they have not done it in practice. Ditto basic mechanisms and levers - part of technology POS.

I am picking up that you are a bit negative about problem solving in science.

M - No, sceptical and cynical. I have been seriously into problem solving in the full meaning of the idea for a long, long time. To do it properly requires a whole change in pedagogy, it is very time consuming. It needs a lot of planning and thought. To apparently have something just humming, kids working individually and well is the state of the art in teaching. The Smallpiece trust will come in and do the potatoes and cocktail type of stuff, we have no truck with then any longer, it is farting about with two copies of the Guardian and putting a bulb on the top. [Intermediate tech not included]

Do you agree?

R - Yes I do the same applies to food tech. A lot of what we have been doing has been hijacked eg using yeast, testing fabrics. Having done that in the academic echelons of science, children can very easily become blase saying that we have done it. Very often we do feel a resentment that everyone is an expert on food. It is seen as something interesting for children. Because you see yourself to be an expert on food you can teach it. e.g. geog display says there is vitamin C in an egg.

We have few girls in science and engineering. Why is this?

R - It is not to do with ability at all. It is to do with biology. I feel quite strongly that males are males and females are females and however strongly we try to make the two one,
It is something much more basic than unisex toys, which extreme feminists fail to see. Many girls are simply not turned on by a car, many boys by a doll. That is the way it is. A majority of boys tend towards the masculine activities of life and the majority of girls naturally tend towards feminine.

How do the see the masculine in science and technology?

Until recently women have not had a say in how anything is done in this world. Her chances were very limit and still are. There is something innate. There are those in between and the boys will become nurses and girls will become engineers.

Where is science and technology in this?

Technology which I see as a harder subject than science, I see science as theoretical and tech as slightly harder. If you look at the design technology area, not talking about the food technology area you have many more boys in the hard technology. Having had boys in food technology 6-10 yrs there was this prossy attitude to it but now they accept food as an alright thing to do and girls see hard tech as OK. That is probably due to NC. They will not now say we are going to cookery, they might say today we are going to cook but we don't have a subject called cookery here anymore. There are more girls in medicine than other areas of science and technology because it is a caring profession.

And science and technology are not?

R - Not at all
M - Not is the same way. We are talking stereotyping - women in sharing, caring roles. Arguably someone has failed somewhere.

R - I don't see as failing at all, each of us is better at some things than another.

M - Pre NC we had a smattering of girls 17%, higher than the national average.
R - and the same with boys in HE.
M - Not something to be satisfied about.
R - or be concerned about.

M - Many girls who have done tech in year 9 have parent who are in trades like carpentry and electronics. These parents are presumably not stereotyping - "If it is good enough for me it is good enough for you." NC will probably produce more girls, they can see us [the two of them] working together and it works. The is no demarcation between one area and another it is all technology. They go to the room where the facilities are.

If the engineering council and HMI get there way it may move more towards CDT....

M - This is the power struggle which is going on at the top. In early days it was business studies and the foodies were marginalised and Baker had them pinned out. They have come back but there is little reference to food, it has been put to one side. One reason for revising the orders is to put food back into place.
Working with home economics teachers over the past few years I have found they are feeling very insecure.....

M - Yes they feel threatened. These are perceptions, if for a person in my position (head of faculty) or indeed headmasters is well there is no reference to food here, sod them. There is evidence some food work has been abandoned or put on low heat in some schools.

R and I do a double act to other schools and advisers and show how well we get on, we show a seamless front. it is the chippies in my area who are the problem, they are hope to keep their heads down and it will pass. When I was head of CDT I had little contact with HE. It is about micropolitics. many are still bitching about colleagues and talking about the reasons why they can't get together.

R is the anything more you want to say?

R - He can be taught in a thousand ways and at different levels.
Is that being seen by the people who have the power?

No it is not, despite the government's view about health they do not grasp the need to teach about healthy diet.

The use of nuclear energy and gen eng and who should decide.

M - There are different issues...
R - Gen eng is a very complex issue and the last person to make a decision is Joe Bloggs in the street. Nuclear energy it should not be scientists alone in either case. Politicians and scientists should work together and not the man in the street.

Would you include discussions of how decisions are made or the values judgements which are brought to bear in decision making with you pupils?

R - I don't think children are able to do this, their views are tainted by what they have read in magazines like 17. All the time we are asking children to make judgements based on practically no knowledge.

M - No difference in the two areas, they are both complex areas. The system we have is probably the best, in that checks are provided by the learned bodies such as Greenpeace, Friends of the Earth. The challenge to see if impartial decision making is taking place. we need people like Baroness Warnock to say what people are feeling to check the scientists. It is great, it is fun to push the frontiers on knowledge, but...

Scientific models questions.

R - I did not feel in a position to make a judgement on that.

M - All models are flawed because of the data which has been put into it. I see then as mathematical. Scientists are less sceptical than technologists maybe because they have put so much into it. A good scientist assumes phenomena will be consistent and people like
me who see every step forward as having an equal drawback will also have doubts.

Before we started R the HE teacher asked if the two interviews could be done together. I said yes providing you will both speak you mind and one person will not be put off by the other. She said that would not happen because we get on very well.

Time of speaking: M 44mins, R 17mins  R spoke for 7 mins when a man came into the room to talk to M.

After M had left the room, we had an informal chat and the tape recorder was switched on . Some points from R:

I think there will be enormous change in structure although it is a lot more comfortable for men if women stay in the home. More and women are taking on careers as opposed to jobs, many working in society have worked very hard to get where they are. In my lifetime things have come on very far but we have a long way to go. I fear for the family however.

Men often dismiss women's views by saying say it is their age, PMT or menopause. Male and females have different skills and the differences need to be equally valued. I think women see things as grey while men see things as black and white.
INTERVIEW 18 Female chemist/engineer/researcher (18 fe/r)

What do you understand science to be?

Science is concerned with trying to explain how and why things happen in a non-emotional sense. It is not about how people feel about things but why something functions. How does it function? It is not purely a mechanical thing but I separate it from why do we like something, an emotional response.

Is science different from other areas of knowledge?

Yes but I don’t know why. It should be non-emotional. OK one can never be totally sure and can place different value judgements on the possible results but it is basically that there is an explanation. We may not know it at the moment, whereas I see things as the Arts as being an emotional response. A picture evokes a response, it is not necessarily good or bad, whereas some science at the moment is still in dispute, given enough time resources etc there will be an answer to the majority of things. I see that as being the divide. They involve similar levels of mental activity, I feel that science is more concrete.

You said something about value judgements on the findings or results. Can I ask you to think about the process of science, what the scientist does. Are there value judgements involved in the process?

Sure yes. As a scientist there are lots and lots of things one could develop if one had time to, at an initial stage you make a value judgement. "I am going to do this because I believe it should be done" "Because I personally find it interesting although no one else does" "It is something we need as a community." Not so much in my field but certainly in terms of the biosciences there are all the ethical issues. Scientists would like to be able to do ...whatever but should they be allowed to? One could say that in material sciences we have a lesser problem. We could talk about materials for weapons, some people do actively or do not actively pursue work because of moral judgements.

What do you understand by technology?

First thing that springs to mind is gadgets. Technology is the implementation of science, of making science work on a more massive scale; of taking the ideas, the thoughts and turning them into a product and exploiting them in that sort of way. Technology is more making things, developing things, making things work.

Why do this?

It is different from science, science is to do with answering the questions, technology is harnessing that knowledge and making it work for, in most instances, people. The motivation for science is not necessarily doing things for people. Ultimately one hopes that it will in your view lead to a better world but I can believe that it will be a better world if we understand things more. I would not criticise people doing astrophysics but you cannot see readily how that information can be harnessed and put to use for people here and now.

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Is that pure science?

Yes, I tend not to use those sort of terms because I personally feel that the purity is in terms of the strength of the argument, whether you can carry that argument through to a logical final conclusion.

Do you know much of what is happening in school science and technology?

A little, I am a neighbourhood engineer to a local school and I was also an admissions tutor for three years. For the average student the thoughts behind the changes in the National Curriculum are good. I'm not sure they are realistic and can be implemented. I think the concept of making science and tech a fundamental part of education is a very valuable aim.

Combined science or integrated science is good for the average student. It gets them to view science as a whole. It puts it in a reasonable form for them. The disadvantage for the more able student is that the people who are definitely going to want to do science at a higher level and are already motivated and interested are not getting enough science. And it is a bit of a shock for them when they go into the A level system, they have not got the fundamental grounding. The lower end of the spectrum - you are going to have problems with those people.

What of the technology?

The school I work with has a very good approach to technology, I am very impressed. The head of technology is very good, he has been in industry, he makes it work and he involves the scientists.

Does food technology come into that? Is there any home economics input?

I don't know. I find it odd that food technology is part of technology. I wonder whether that is softening it and making it palatable for the people who do not want to do what they would consider to be the heavier technology. I think they should have softened it with computing. I know nothing about food and textile technology in school however. I know that teachers have said to me it is a soft option of the science options and I can see why it is attractive to schools, the materials cost less, the cost of a pound of apples perhaps when steel is more costly.

What sort of teachers?

A level chemistry and physics teachers, mainly chemists. I have not spoken to biology or home economics teachers. Chemistry teachers making choices about options will frequently choose food science because of the cost of resources. I am also conscious of stereotyping, you find by and large, it is the females that go into the biological sciences and the males go into the more engineering/ physical sciences. The roles should be reversed.

Why do you think we have this problem?

I don't really know. I guess sexual stereotyping must come into this very early, girls tend to be bought dolls and toy cookers, boys are given racing cars and engines.
Working in schools do you see any stereotyping?

The small number of teachers I work with are very good in that they portray science and technology as being open to all. They have females in their young engineers club. They then get stifled mainly by outside influences, school gives a very positive attitude, open to all, all come along and in that way they recruit a mixed bunch. They went to a local company to look round and the MD said where are your boys then? Of course they had girls in the party, it is that sort of attitude which can undo so much hard work. I must admit that the one female in a group I worked with recently carried out the admin/housekeeping role for the group. You see this with undergrads. The girls do the note taking, recording, the lads shout out the temperature and the girls write it down. We don't deliberately do anything about that. We do get female/female pairs and male /male pairs. Throughout males are encouraged to be more adventurous physically, they will be introduced to sports rough and tumble at a very early age. Parents handle male children much more boisterously.

Did you go to an all girls schools?

I went to an all girls grammar school but I did my A levels in a mixed college. You cannot hide from the fact that when you graduate there is still discrimination out there. It is very difficult to reconcile what you are telling female undergrads with what you know to be true. As a female engineer you tend to polarise into one of two camps. You either decide to be one of the lads and do everything they do and wear dungarees and what ever and you are going to swear as much as they do, or you go the opposite way to preserve your femininity as much as possible and wear the Laura Ashley frocks and be terribly helpless and play it to your advantage and you get a lot of females who play this role. They get the help and then possibly come out on top. It is very difficult to preserve their own identity. It is also difficult for male colleagues, they feel they have to be roughty toughty engineers and is difficult for them to be more emotional about things.

Will you look at the question about men influencing science, any comments?

Men have definitely influenced the way science is done, previously it has been a masculine activity although I am not convinced that if women had done it would have been done differently. I think the outcomes would be the same, the process may well have been different. The one thing which is always forgotten is the women's role in science. People like Marie Curie get largely forgotten. Her contribution was as much as her husbands, more so possibly. There have been some great women scientists over the years who have been ignored. Rosalind Franklin spurred on Crick and Watson. I think when we say primarily a masculine activity it has diversified so much that I would not say it is. It probably is in the way it is carried out, but it does not have to be, it should not be. I was very disturbed the other week when they were talking about chess grand masters. It was said women can't play chess they are just not able to, they are not built that way. Presumably the people saying this are fairly intelligent, how can they possibly say this? What makes them think that women can't think? I believe you can be taught to think logically, you can be exposed to enough material, if you don't naturally have it certainly your ability can be much improved. They can be trained in the same way as men.
Would you want them to be trained in the same way? Do they have to conform?

It depends if you are going for short term gain or long term gain. I would feel that if you are trying to produce a science graduate and they are going to go out and work in what is technically a male dominated industry, you have a choice. You can try to make the best possible scientist and accept that they are going to be very unhappy or you can say look you are going out to function in a male world, this is how males do it, if you want to play their game this is what you have to do. Someone has to be very mature in their thinking to take that at 21/22yrs. I learnt the hard way, you have to say I am going to play their game or I am not in which case you have to accept I am not going to get promoted and necessarily be fulfilled in that side of my life, but say my science is OK. It is a very difficult thing to reconcile.

Some people have said it is a moral issue, that it is uncomfortable to encourage girls into this. Should we do it?

It is difficult at the moment to encourage anyone to go into science, due to the Thatcher era. If you are a bright female you would be much better off in business studies or administration or law. You have a higher status even though you might be disadvantaged in that profession. I have read that the reason women are not seen to succeed is that the performance indicators are male, written by men for men. Qualities that women have are not assessed or if they are, they are deemed to be negative. If a women is fighting for her career she is hard-nosed or aggressive whereas a man is ambitious and that is OK in a man. It somehow decreases your femininity if you are doing that. It would be interesting to look at exam papers I set and compare how the women do on my exam papers compared to the men. - or if my marking is different.

Is a scientific fact a word that you use? What is a scientific fact?

I do use it all the time but when I am really made to examine it well.. A fact is something that has yet to be disproved. There is still the possibility we are wrong. Facts are things that have not been disproved yet and we base our subsequent reasoning on them.

Is science about disproving?

There is an element of that in it. You set yourself up as a target and you say well that can’t possibly be right because of x,y,z. But in a way that is not the prime driving force, likewise I don’t think they are trying to prove something. It much more I just want to find out. If our prime driving force was to disprove we would become cynical and disappointed with the world, whereas if we set ourselves a target to improve....

Is there a difference between improving the world and disproving my hypothesis, my theory?

The ultimate reason for setting one self up is try to get to the ultimate answer. In doing that they may set themselves up these false targets but I think they rarely set out to disprove something.
You think they want to prove the hypothesis?

Yes and I think they can get over-enthusiastic about that and to try to disprove is a natural counterbalance to just gathering the evidence to support your claim. One has to always be careful. I tend not to work that way either. I work sort of .."OK I don’t know anything about this, let’s see what we can find out." I try to keep a much more open mind. If you get fanatical about things you bias the way you do things.

This is a different picture than the person in the street might have.

You are human, you have emotions about what you are doing to start with and half the battle is to stop your prejudices and emotions colouring your judgements. We should be heading towards objectivity but you can’t do that. You have to do that from a personal background. With students working on projects, I will be hoping it goes a certain way, but I have to try to keep this back, and be guarded, particulary from them and find out what they are doing.

There is mention of scientists working by instinct and intuition. Is that so?

Yes

Do you acknowledge that, do you talk about that?

Yes, not in the written form, but certainly with students and colleagues. Yes all the time.

There are two questions on who should make decisions. Do you see any difference between nuclear energy and gen eng in who should be making the decisions?

No. They are both going to have massive effects on human life. I am not familiar with either, I am just a member of the public on those. I think they should be heavily debated. I think one of the problems with asking the general public too much is that they are not scientists and you cannot possibly explain all the detailed ins and outs. It is like me on Maastricht, I do not have a clue about what is going on. I can read the document but at the end of the day you have to take someone’s advice. Decision should not be handed over completely to the scientists because we get too fanatical, we want to do some things for science sake, not necessarily for mankind as a whole. We do not always appreciate what we have done until it is too late, then you run into moral dilemmas for example about whether it should have been done in the first place, it is too late then.

After the tape had been switched off the interviewee commented that there where more females graduating this year than males. This was because men had dropped out. They had not the dedication, staying power and commitment of the girls. It was not to do with ability. The girls needed to be treated differently.