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A literature review of research conducted on young people's attitudes to science education and biomedical science.

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A literature review of research conducted on young people's attitudes to science education and biomedical science

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Introduction

This review aims to determine what issues have been covered by research in this area since 1980, highlighting what is known and unknown and to inform discussion about the potential of the proposed Wellcome Monitor for exploring the knowledge, interests and attitudes of young people to the biosciences.
It is written against a backdrop of continuing concern about public perceptions of aspects of science, public knowledge and understanding about science, and the number of young people choosing to study science beyond the age of compulsory education in the UK and other developed countries.

Methods

The review was conducted in two phases, adopting a modified version of a model developed by the Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI-Centre) for the systematic review of literature. Phase one involved searching and screening potential abstracts of papers according to clearly defined criteria for inclusion in the review. Phase two entailed analysis of full papers, utilising the same criteria for inclusion, summarising content of relevant papers and writing of the review.

Findings

Findings are grouped according to the key issues addressed in the literature:

1. Young people develop stereotypical images of science and scientists from an early age and these images are resistant to change, which has implications for subject choice and consideration of science-related careers among young people.
2. Classroom environment and perceived quality of teaching in science are found to be influential in determining attitudes toward science education among young people. Perceptions of quality of science teaching decline as pupils move from primary school into secondary school.
3. There is lack of agreement among researchers about the strength of parental and peer influence on young people's attitudes toward science. This may be the result of ill-defined or inconsistent measures of influence, particularly related to peer groups.
4. Evidence concerning the influence of culture and ethnicity on attitudes towards science is inconclusive though there is a history of lowered involvement in science among some ethnic groups, the reasons for which remain unclear.
5. Boys continue to express consistently more positive attitudes toward many aspects of science than do girls. However, girls express consistently more positive attitudes toward biology, particularly human biology, and areas of science that reward imagination and aesthetic appreciation. Girls tend to do slightly better than boys at GCSE level in biology and chemistry, though boys achieve higher scores in physics.
6. Intervention programmes designed to improve attitudes towards science, including biosciences, tend to show positive short-term effects.

What is not known is the extent to which improvements in attitudes as a result of such interventions are sustained.

7. Evidence of a correlation between achievement and attitudes toward science is inconclusive. However, evidence of a correlation between achievement motivation and attitude emerged from one study.
8. Findings of longitudinal studies provide convincing evidence of a steady decline in young people's attitudes towards science over time, beginning towards the end of primary school.
9. International projects such the longitudinal Relevance of Science Education (ROSE) project have important implications for the proposed Wellcome Monitor, particularly in the development of quantitative research instruments for the measurement of attitudes that facilitate comparison between groups of young people of similar age.

Conclusion and recommendations

The findings above highlight the complexity and multi-faceted nature of this area of research. While many of the studies analysed for this review make an important contribution to our understanding of the factors influencing young people's attitudes toward science and the biosciences, there remains considerable scope for further research.

The following recommendations are informed by the findings of this literature and take account of the objectives of the proposed Wellcome Monitor:

1. To address stereotypical images of science and scientists among young people, future research into attitudes toward science and the biosciences in particular needs to include scrutiny of resources and materials, including videos and interactive computer software used to evaluate the extent to which they present realistic images of science and scientists.
2. Research needs to identify the nature of quality teaching in science as perceived by young people. Outcomes would support teachers in the development of practice and provide insight into possible reasons for a decline in perceptions of quality teaching in science as pupils move from primary to secondary schools.
3. Lack of conclusive evidence concerning the strength of influence of parents and peers on attitudes to science leads to the recommendation for focused research in this area, taking account of the need to develop well defined instruments of measure to ensure reliability.
4. An in-depth exploration of cultural and ethnic influences on attitudes toward science is needed to inform initiatives designed, among other things, to ensure that scientists are representative of the society in which they work.
5. Further research should investigate why girls have significantly more positive attitudes toward biology than to the physical sciences as this will help to inform subsequent steps toward improving their attitudes to physics and chemistry.
6. Longitudinal research is needed to determine the extent to which intervention programmes, designed to improve attitudes toward

science, are successful in instigating sustained change in attitudes toward science among young people.

7. Lack of conclusive evidence concerning a possible correlation between achievement and attitudes signals the needs for further study. Work is needed to ascertain the extent to which a correlation exists in young people between motivation to learn science and attitudes toward science among young people.
8. A longitudinal research study needs to track the steady and at present apparently irreversible decline in attitudes toward science among young people over time in an effort to more fully understand why once attitudes begin to decline they continue to do so.
9. The dearth of studies that explore attitudes of young people toward biomedical science suggests there is considerable scope for research in this area. Consideration needs to be given to the extent to which intervention programmes will be required to ensure that the young people involved have a level of scientific knowledge and understanding sufficient to enable them to offer informed views.
10. Appropriate research methodology to support the aims and objectives of the proposed Wellcome Monitor should take account of the need to understand not only the nature of young people's attitudes toward science and the biosciences but also *why* they hold these attitudes. Such insight would help to inform future developments in science curricula and instructional strategies in the sciences.

Introduction

Over the past 30 to 40 years, young people's attitudes towards studying science have been the subject of intense investigation by the science education research community, reflecting continuing concern about the steady decline in numbers of young people opting to continue science courses, particularly physics and chemistry, beyond the age of compulsory schooling or pursuing science-related careers in the UK and other countries (DfES, 1994; Smithers & Robinson, 1988; Osborne *et al.,* 2003). Alongside this, concern is growing about the widespread lack of scientific literacy among the general populace of developed countries (Durrant & Bauer, 1997), and the increasing shortage of professional scientists and engineers in the UK over the next two decades (Jenkins, 1994). The situation is compounded by a lack of well-qualified science teachers, a state of affairs that looks certain to worsen in at least the short term.

It is against this background that this review explores current understanding about young people's attitudes toward science and biomedical science, the factors influencing the formation and change of attitudes and implications for the development of a Wellcome Monitor in informing future policy and practice in science education.

Background

Despite the overall rise in numbers of undergraduates in the UK, the take-up of the physical sciences at A level and some science subjects at university continues to decline (Haste, 2004). Concerns were expressed in a recent report of a conference hosted by The Royal Society (2006), in which the Chair of the Education Committee drew attention to the fact that despite an increase of almost 85 000 (12.1 per cent) A-level entries in England and Northern Ireland between 1991 and 2005, there had been significant decreases in uptake of traditional sciences and mathematics. The 2005 A-level entries for physics and chemistry were respectively 35.2 per cent and 12.6 per cent lower than in 1991; however, biology was the exception to this trend with entries rising by 15.8 per cent over the same period.

Speaking at the conference, Professors E Jenkins and J Donnelly attempted to shed some light on the reasons for the steady decline in post-16 uptake of science over the past decade. Decline had coincided with a period of considerable reform in science education, implemented with unprecedented speed, with the effect of unsettling the science education community, leaving science teachers facing an uncertain period of change. Importantly for this review, their recommendations for action included greater attention on young people's attitudes to and perceptions of science, and investigations of the ways in which science is organised and supported in those schools with a positive record in encouraging pupils to pursue science courses post-16 years.

The proposed Wellcome Monitor is a timely response both to concerns and recommendations expressed above. While the proposed focus of the Monitor is biosciences, the intention to address issues such as intention to study science post-16, scientific career opportunities and the impact of science on young people's lives and on society, suggests research outcomes of potential significance for science education as a whole.

Aims and objectives

The main aim of this review is to provide reliable evidence to inform discussion about the potential of the proposed Wellcome Monitor to explore young people's attitudes, knowledge and interest in the biosciences. Specific objectives leading towards this aim include:

- examination of the issues covered to date in research on young people's attitudes toward science education and to the biosciences
- exploration of what is known and unknown about young people's attitudes toward science and the biosciences.

Methods

The methods adopted for this systematic review of literature were based on those developed by the Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI-Centre). In essence this means that the worth of a paper, report or other publication to the review is evaluated quantitatively with regard to the quality of its data and analysis. Although the team followed standard EPPI procedures in the selection of papers for inclusion, modifications were made at the stage of close document analysis to take account of the substantial body of literature on young people's attitudes toward science worthy of inclusion in the review.

Phase 1

The first phase of this review began on 15 May 2006, with initial searching and screening of a broad range of studies that met the characteristics of the review, while maintaining a flexible approach to ensure the smallest number of relevant studies might be excluded. Identification of potential studies was confined to those conducted with young people between the ages of 9 and 19 years. The lower age group was included to ensure the capture of relevant studies conducted in primary/elementary schools.

The search strategy utilised electronic databases, online and library handsearches, and selected websites (Appendix 1.1). Key journals were searched for potentially relevant papers using one or more electronic databases. Handsearching was carried out for the majority of journals for the period 1980 to 1995, as these volumes were found to be unavailable electronically (Appendix 1.2). Searches were chronological to facilitate retrieval of studies published or reported after 1980 and selection of studies was restricted to those written in English. Geographical limits were not imposed and studies conducted in countries other than the UK, mainland Europe and the USA were selected where they met the broad criteria for selection (Appendix 1.3)

While initial searches were successful in identifying a range of studies that met inclusion criteria in broad terms (approximately 500 studies), few studies focusing specifically on the attitudes of young people toward biomedical science were found. Leading individuals in the field of science education and research were contacted for assistance (Appendix 1.4) and responses helped to identify a small number (approximately eight) of potentially relevant studies.

The final stage of phase one involved title and abstract screening of papers. Following title screening, 450 papers remained for abstract screening. Each abstract was coded using criteria for inclusion and exclusion agreed by the team (Appendix 1.5a) and notes added to clarify decisions (Appendix 1.5b). After abstract screening, de-duplication and setting aside papers of potential interest for theoretical background, 233 papers remained for possible inclusion in the review; of these, 152 met a number of key screening criteria, including 14 papers with potential relevance to biomedical science and a further 81 papers requiring full document screening to ascertain their relevance as abstracts of these papers offered insufficient detail to facilitate coding.

Phase 2

The second phase of the review adopted a modified EPPI model, to take account of the large number of full documents to be screened in a short time, prior the writing of the review. A two-stage process was introduced as follows:

Stage 1: full documents were coded against the same criteria as those applied for the screening of titles and abstracts (Appendix 1.5a). This allowed for the checking of papers against the full set of codes to identify aspects of studies rarely included in abstracts.

Stage 2: full documents found to meet the full set of criteria were summarised, using the items set out in our proposal (Appendix 1.6), and grouped according to main characteristics, for example, *intervention programmes; focus on gender; attitude and achievement*.

Of the original 233 papers for full document screening, ten could not be found, either because they were conference papers that were unobtainable, or were papers published in obscure journals, which could not be accessed electronically or from the Institute of Education library. The process of full document screening resulted in the rejection of 42 papers. A number of papers (N=31), on full reading, were found to meet an insufficient number of the criteria for inclusion, the remainder (N=11) included duplication of research studies where two or more authors had published findings of the same study, but where one author covered in greater depth issues of interest for this review.

On completion of full document screening a total of 181 papers met key criteria for inclusion. In order to do justice to a significant body of research in the area of young people’s attitudes toward science and biomedical science, the review draws together studies with a common focus, enabling a review of current knowledge about attitudes toward science and biomedical science, influences on their formation and their impact in terms of uptake of science courses and career decisions.

Issues in attitude research

Attitude research has come in for considerable criticism on a number of fronts during the past 30 years (Gardner, 1975; Schibeci, 1984; Munby, 1990).

Germann (1988) pointed to the vagueness, inconsistency and ambiguity of the meaning of the term ‘attitude’ and the lack of a clearly articulated theoretical model of the relationship between attitudes toward science education and other variables – such as gender, peer and family influence, teaching styles and the school science curriculum – in many studies. In addition, inadequate and ‘immature’ attitude measurement instruments have been strongly criticised by Gardiner (1975) and Munby (1983) for inconsistency of results and lack of reliability.

Attitudes toward science

The call for clarity in describing concepts under investigation is a common theme through the literature in this area. Koballa (1988) pointed to a need for science educators to define the term ‘attitude’ carefully if we are to understand and predict the science-related behaviours of young people. The reasoning for this becomes clear when considering the variety of terms used in the literature analysed for this review, for instance reference is made to young people’s ‘interest’, ‘motivation’, ‘views’, ‘opinions’, ‘images’, ‘beliefs’ or ‘attitude’ toward science education. Although these terms are sometimes used interchangeably, or with a degree of overlap, the definition most frequently quoted in the literature is that of Fishbein and Ajzen (1980), whose *theory of reasoned action* identified a relationship between attitude and behaviour in contending that, ”…attitude can be described as a learned predisposition to respond in a consistently favourable or unfavourable manner toward an attitude object” (p. 6). The *attitude object* referred to here includes such factors as ‘science’, or ‘science lessons’, ‘science teacher’, ‘laboratory work’, and so on (Schibeci, 1983; Koballa, 1988).

There has been some confusion concerning differences between *scientific attitudes* and *attitudes toward science* (Munby, 1980; Schibeci, 1984). Different meanings have been applied to these concepts historically (Gardner, 1975; Hasan, 1985; Schibeci, 1984; Shrigley, 1983), though there is less discussion of the differences in more recent papers. *Scientific attitudes* generally centre on the characteristics of scientists, for example, *open-mindedness; curiosity; honesty; scepticism and objectivity*, considered to be appropriate and attainable objective for school science curricula (Munby, 1980; Schibeci, 1983, 1984).

However, defining *attitudes toward science* has proved more problematic as there appears to be diverse meanings attached to such abstruse personal constructs as *individual feelings, opinions, likes* and *beliefs* toward an attitude object. As Koballa (1983) commented, not only has clarity been lacking, but *scientific attitudes* and *attitudes toward science* have sometimes been conflated in assessments of young people’s attitudes, though less evident in more recent studies. A lack of conceptual clarity in assessing attitudes toward science has resulted in difficulties in comparing *attitudes towards science* research (Schibeci, 1983; Shrigley, 1983), leading to calls for further efforts to improve the situation (Koballa, 1984; Schibeci, 1984).

Attitude measurement instruments

Alongside a lack of conceptual clarity related to attitudes, there have long been psychometric problems associated with instruments used to collect attitudinal data (for example Bratt, 1984; Schibeci, 1983, 1984; Ost and White, 1979; Wilson, 1981). If it is correct that attitudes toward science can be expected to predict science-related behaviour (Shrigley, 1990), the development of accurate instruments to assess attitudes must be a primary consideration in the design of studies. However, the proliferation of instruments over the past 30 years is considered problematic by some researchers (Mayer and Richmond, 1982; Munby, 1980), with many of the instruments criticised on both conceptual and empirical grounds (Munby, 1980; Schibeci, 1984).

Many instruments have been developed for specific studies (Table 1) and a lack of flexibility means they may never be used again. Schibeci (1986) called for a set of instruments that could be used, with only minor modifications, in different countries, as this would facilitate direct comparison, not only of young people’s attitudes to science, but also attainment in science. Attempts have been made to answer this call in recent years with the development of the Relevance of Science Education (ROSE) project; an international comparative project intended to shed light on factors influencing attitudes toward science and technology among 15-year-old students. The research instrument in the ROSE project is a questionnaire, administered to students in all participating countries, mostly consisting of closed questions that relate directly to attitudes toward science. The questionnaire was developed in cooperation with ROSE partners from all 23 countries involved in the project. It does not utilise questionnaire items from standard attitude scales, such as those shown in Table 1 below; it is not designed with the intention of testing relationships between variables such as attitudes and preferred subjects, nor attitudes and selection of courses. In short, the aim was not to define research questions, hypotheses or definitions, but to explore ”what is in the mind of the students in different countries” (Schreiner, 2006, p. 19).

Variables/Topical areas	Instrument	Papers
Attitude and achievement	Wareing Attitudes Toward Science Protocol (WASP)	Wareing (1990)
Nuclear energy	Nuclear Energy Attitude Scale (NEAS)	Showers & Shrigley (1995)
Student, teacher and learning environment	Inventory of Affective Aspects of Schooling (IAAS)	Haladyna *et al.* (1982)
General Attitudes to Science	Attitude Toward Subject Science Scale (ATSSS)	Krynowsky (1988)
	Science Attitude Inventory (SAI)	Munby (1983)
	Science-Related Attitude Instrument (SRAI)	Dulski & Raven (1994)
	Student Opinion Survey in Chemistry (SOSC)	Schibeci (1986)
Cross-cultural issues High-ability students	Test of Science Related Attitudes (TOSRA)	Khalili (1987) Joyce & Farenga (1999)
Biology	Test of Biology Related Attitudes (TOBRA)	Rideng & Schibeci (1984)
Informal science experiences	Science Experiences Survey (SES)	Mason & Kahle (1988)
Gender	Women in Science Scale (WiSS)	Erb & Smith (1984)

Table 1. Example of instruments used to measure attitudes toward science

The instruments shown in the above table illustrate the wide variety of methods for the assessment of attitudes to science. While there has been some development in instrument design to facilitate data collection within specific topic areas or variables, the fundamental methods of measurements have changed little in the past 40 years and include: *differential scales; rating scales; summated rating scales; semantic differential scales; interest inventories* and *preference rankings* (see Appendix 2; p. 72). The most frequently used method has been the *summated rating* method, usually referred to as the *Likert scale*, developed by Moore and Sutman (1970), and further developed by Fraser (1978; 1981) to provide the Test of Science Related Attitudes (TOSRA), a useful example to outline here as it utilises a framework common to the great majority of studies analysed for this review. The original TOSRA comprised seven subscales and ten statements (items) for each subscale, including:

- *Social implications of science;* measures attitude regarding the positive and negative effects of science on society, e.g. 'Scientific discoveries do more harm than good'.
- *Enjoyment of science lessons;* assesses level of enjoyment of science lessons, e.g. 'Science lessons are fun'.

- *Career interest in science;* measures interest in a future science-related career, e.g. ‘When I leave school, I would like to work with people who make discoveries in science.
- *Leisure interest in science;* probes willingness to engage in informal science-related activities, e.g. ‘I would like to be given a science book or a piece of scientific equipment as a present’.
- *Attitude to scientific enquiry;* probes liking for the use of inquiry in science, e.g. ‘It is better to ask the teacher the answer than to find it out by doing experiments’.
- *Adoption of scientific attitudes;* measures readiness to adapt or revise views based on experimentation and empirical data, e.g. ‘I am curious about the world in which we live’.
- *Normality of scientists*; assesses belief about the lifestyle of scientists, e.g. ‘If you met a scientist, he would probably look like anyone else you might meet’ (Fraser, 1981; Joyce and Farenga, 1999).

In developing this model, a large pool of items was examined and agreed by a group of science educators; a practice subsequently adopted by researchers in modifying the instrument to gather data on specific variables or science topics. Selected statements were then attached to a five-point Likert scale ranging from ‘strongly agree’ to ‘strongly disagree’, with ‘undecided’ as the pivotal point on the scale.

The attention awarded TOSRA may be attributable partly to its multidimensional nature and apparently sound conceptual basis or, as Haldyna and Shaughnessy (1982) put it, “TOSRA is an outstanding instrument because it has sound theoretical basis and an impressive empirical validation” (p. 549). The importance of TOSRA in more recent research has been its use in measuring more than one dimension of attitudes toward science (Shrigley, 1983). Questions concerning the extent to which the instrument is transferable from its original use with Australian youngsters at the lower high school level to other countries and age groups of young people have now to have been answered, in part at least, with successful studies undertaken by Khalili (1987) and Joyce and Farenga (1999) in the USA.

Analysis of data

Validation of an instrument is essential in any research that needs to make statistically significant comparisons between groups of students. This has been a problem with so many instruments used in attitude research – they make it impossible to compare results obtained from different studies in the same and other countries, in part because it cannot be assumed, for instance, that an instrument shown to be valid in use with young people in Australia would necessarily apply to young people of the same age in the UK.

Most of the studies contributing to this review have utilised quantitative methodologies employing with factor analyses, multiple regressions and Cronbach alpha coefficients to assess the internal consistency of scales and occasionally the correlations of scales with other scales. The use of computer software to support data analysis is becoming more popular, for example, Kohr’s computer programme (1973), typically used to analyse Likert items, which is little more than a frequency count of responses made by respondents to each item on the questionnaire. Another example is the LISREL VI computer programme (Jöreskog, 1978), designed to support LISREL, a general model for the analysis of covariant structures, originally devised by Jöreskog (1973), and used to support causal modelling procedures in studies that seek to investigate different relationships between variables, for instance, attitude and achievement in science (e.g. Schibeci and Riley, 1986; Rennie and Punch, 1991).

These and other procedures and software tools have been used for the majority of short studies analysed and, while they appear to generate reliable findings, they do not have the power to capture changes in attitudes over a period of time. In considering one of the objectives of the proposed Wellcome Monitor – to include longitudinal research studies – it is important to establish statistical procedures that will capture longitudinal trends in young people's attitudes. Different research studies have utilised different approaches to the measurement of change over time. The majority of longitudinal studies analysed utilised the same questionnaire, typically similar in design to those used for short-term studies, at intervals throughout the period of research. This method has the advantage of consistency of data collection, but it cannot take account of a range of variables that might influence individual attitudes toward science over time.

In an effort to explore the possible nature and influence of a range of variables on attitudes toward science over time, George (2000) developed Latent Variable Growth Modelling*,* combining individual growth modelling with covariant structure analysis (Meredith and Tisak,1984; 1990; Willett, 1994), which facilitated a consideration of the effects of variables outside the environment of the science classroom or school, including individual background, home environment, experiences of science outside the science classroom and school, in conjunction with individual experiences of science education.

Qualitative methods for attitude research

Making the case for qualitative research methodology in assessing attitudes toward science, Potter and Wetherall (1987) maintained that attitude instruments measure only one aspect of individual views and that deeper understanding of attitude toward an object can only be revealed by a study of the attitude in the context of its use. As Osborne *et al.* (2003) pointed out, attitude cannot be separated from its context and the underlying body of influences that determine its real significance. In the case of science education this suggests either a move away from general quantitative measures of attitude constructs towards exploration of the specific issue of young people's attitudes to school science education, or a move towards multiple research methods where qualitative methodology is used to enhance and validate quantitative data.

Studies presenting the most convincing arguments in the literature analysed for this review have been those that utilised 'complementary' methods (Roberts, 1982), where qualitative and quantitative techniques, usually including questionnaires supported by classroom observation, individual structured or semi-structured interviews and group or focus group interviews, have been utilised to good effect in probing pupils' views and opinions on aspects of particular interest to researchers (Ebenezer and Zoller, 1993; Gunter *et al.,* 1998; Hadden and Johnstone, 1982, 1983a, 1983b; Hendley *et al.,*1996; Parkinson *et al.,* 1998; Sinclair, 1994). The main advantage of complementary methods for assessing attitudes toward science is the facility to obtain a broad view of the opinions of large numbers of young people in a relatively short time with the addition of more in-depth understanding of the experiences and attitudes of a smaller number of young people.

Findings from a number of qualitative research projects have provided greater insight into *why* young people think as they do (Piburn and Sidlik, 1992; Piburn and Baker, 1993; Osborne and Collins, 2003; Reiss, 2004). The main drawback is sample size; what is manageable with questionnaire surveys is not possible with focus groups, group interviews or individual interviews and classroom observations.

Issues of validity and reliability for qualitative research are no less problematic than for quantitative methods. As one of us concluded elsewhere (Reiss, 2004), every research instrument used to determine attitudes toward science raises issues of validity. For instance, in utilising qualitative methodology, it is difficult to draw conclusions about a student's attitude from observations made in the classroom. However, information gained during individual interviews, group interviews or focus groups can have a high degree of validity, provided participants feel able to express their views and opinions freely and in confidence.

The importance of attitude research for science education

Koballa (1988) offers perhaps the most compelling argument for studying young people's attitudes toward science. First, attitudes are generally stable over time; they can be changed but not at random. Something needs to affect change and this has important implications for science curricula and instructional strategies. Second, attitudes are learned. Young children are not born with a passion for or aversion toward science education; they learn to like or dislike it. The third strand of the argument centres on the relationship between attitudes and behaviour, or as Koballa puts it, "people's actions reflect their feeling toward relevant objects and issues in a probabilistic way" (p. 124). This assertion has been met with some scepticism among researchers, who remain to be convinced of a one-to-one correspondence between attitude and behaviour, suggesting that young people's behaviour might be influenced by more strongly held attitudes. For example, an individual might express positive feelings about science, but avoid admitting it publicly among his/her peers who regard such positive feelings to be unacceptable (Wareing, 1990; Potter and Wetherall, 1987; Osborne *et al.,* 2003).

Ajzen and Fishbein (1980) throw some light on this debate through their *theory of reasoned action*, which makes a distinction between an *attitude object* and some specific action to be performed towards that *object*, for example, a distinction between attitudes toward science in the broader sense and attitudes towards engagement in school science specifically. For Ajzen and Fishbein it is the latter form of attitude that best predicts behaviour; thus their theory of reasoned action represents a relationship between attitude, intention and behaviour. The theory of reasoned action has been applied to attitude and behaviour studies over the past 20 years (Norwich and Duncan, 1990; Crawley and Black, 1992). Useful examples include studies conducted by Crawley and Coe (1990), Koballa, (1988) and Oliver and Simpson (1988), where peer influence was found to be a strong determinant in individual decisions to pursue science courses, suggesting a valid theory.

As the preceding discussion shows, researching attitudes of young people towards science education is a complex process, requiring careful and unambiguous methodology. What is clear from the literature is that a real effort has been made over several years by the research community to develop techniques for the assessment of young people's attitudes toward science that take account of issues of validity and reliability, though these have not yet been fully resolved. We now know that any study of attitudes needs to be underpinned by clear definitions of the terms *attitude* and *attitude towards science*. Although a considerable number of variations in quantitative instruments of measurement of attitudes toward science have been used to support exploration of specific variables and factors influencing young people's attitudes toward science, there is a growing acceptance among researchers of the need to devise/develop instruments that facilitate comparison between different groups of young people, within and across countries.

A number of issues raised in this section have implications for the proposed Wellcome Monitor. Quantitative instruments used to assess attitudes towards science in the literature analysed for this review reflect, to a greater or lesser degree, an understanding of the definitions of both *attitude* and *attitudes toward science,* though future research in this area would need to be underpinned by clearly defined terms, reflected in proposed methods of data collection and analysis to address issues of reliability and validity. Methods utilised for longitudinal research need to give due consideration to factors outside the school environment that are likely to influence the attitudes of young people toward science over time. A consideration of complementary methods for both short-term and longer longitudinal research is needed in an effort to address issues of reliability and worth in quantitative research methodology.

Findings

Over the past 30 or so years, research projects conducted to assess attitudes toward science among young people have tended to focus on one or two clearly defined factors, or variables, in an effort to measure the countless subtopics in this area of research and for logistical reasons, to keep recording and analysis at a manageable level. This practice is reflected in the organisation of this section of the literature review, arranged under headings according to variables and/or factors that underpin the studies analysed. Examples of questionnaire statements/items for each variable are provided in Appendix 3 (p. 74).

Images of science and scientists

Images of scientists and scientific work have long been associated with declining uptake of science post-16 years. Young people's images of science and scientists develop as a result of visual and verbal images from film, television, fiction and textbooks. These perceptions can prove remarkably resistant to change (Schibeci and Sorensen, 1983) and are likely to affect attitudes toward science in one of two ways. Firstly, if we accept Koballa's (1988) claim that belief is strongly associated with an object, then young people who believe that school science is typified by difficulty, right answers and boredom may well demonstrate negative attitudes in various ways (Mason and Kahle, 1989). Secondly, commonly held stereotypical views of science among young people (Stables, 1996), together with narrow views of the work of scientists (Furlong and Biggart, 1999; Hill and Wheeler, 1991), may lead young people to assume that they have to be a genius to be a scientist, to enjoy working in isolation, with a limited social life. If these perceptions do not attune with individual aspirations for the future, they are unlikely to consider a career in science (Yager and Yager, 1985; Mason and Kahle, 1989).

The majority of studies undertaken in this area over the past 20 years have utilised some form of the Draw-A-Scientist Test (DAST), devised by Chambers (1983) to facilitate a study of perceptions of scientists among 4800 pupils aged 5 to 11 years in the USA. Individual pupils' drawings were analysed using seven standard indicators: *lab coat; eye glasses; facial hair (beard, moustache, sideburns); symbols of research (scientific instruments, lab equipment); symbols of knowledge (books, filing cabinets); technology ('products of science'); relevant captions (formulae, taxonomic classification.* Results showed the development of stereotypical images of scientists began at an early age (approximately seven years old), with more standard indicators appearing in pupils' drawings with increased age.

Several studies over the past two decades have utilised the DAST to assess young people's images of science (Finson *et al.,* 1995; Fort and Varney, 1989; Jarvis, 1996; Mason *et al.,* 1991; Matthews, 1994; Matthews, 1996; Newton and Newton, 1993; Schibeci and Sorensen, 1983; Tuckey, 1992). Each study has provided evidence of similarly stereotypical views among pupils, particularly those in the primary/elementary school age range. Matthews (1996) found that despite efforts of science curriculum developers in the USA to depict scientists of both sexes, from different walks of life and a variety of racial and ethnic backgrounds, the majority of students perceived scientists to be old, white and male. Young people's views of the work of scientists tend to be restricted to solitary laboratory experiments, frequently featuring dangerous chemicals (Chambers, 1983; Finson *et al.,* 1995; Tuckey, 1992).

However, Maoldomhnaigh and Hunt (1989), investigating factors that influence primary school pupils' perceptions of scientists in the UK, found that older pupils (age 10 to 11 years) were inclined to have more than one image of the 'scientist' and were therefore likely to draw different images at different times, regardless of interventions. Furthermore, they found that changes in instructions given to pupils resulted in differences in drawings. While this underscores the importance of a standardised instrument such as DAST, to ensure reliability, it is important to note that regardless of altered instructions, Maoldomhnaigh and Hunt identified a range of stereotypical images almost identical to those of others studies conducted with pupils of a similar age using standard DAST procedures.

While studies utilising DAST have focused mainly on younger pupils, a few have attempted to identify secondary/high school students' images of science and to offer guidance to teachers in the use of DAST as a starting point for improving young people's attitudes toward science (Kahle, 1988; Kelly, 1985). In one UK study, conducted by Matthews and Davies (1999) to explore images of science and scientists among 281 5 to 11 year olds and 132 11 to 13 year olds, pupils were asked to draw an imagined pair of scientists to facilitate an investigation of issues related to gender, race, social relevance and collaboration in science in pupils' drawings. Results showed that pupils' images of scientists grew increasingly male as they grew older. Though some 5- to 6-year-old girls were likely to draw female images, by the time pupils reached secondary school, 66 per cent of drawings featured males and 34 per cent females. Regardless of the number of ethnic minority groups in the classes represented in the study, pupils had an overwhelming image of scientists as white. However, when pupils in a year 6 class (age 11 years) were asked to specify clearly if their figures were black or white, a higher percentage of pupils drew black scientists. This confirms Maoldomhnaigh and Hunt's findings (1989) that images are influenced by the instructions given. However, Matthews and Davies (1999) claimed that such changes were the result of a heightened awareness of such issues as race and gender among pupils. Pupils' views of the cooperative and collaborative nature of science, depicted in relationships between the two drawn images, showed that pupils did not view science as having a marked social dimension. The authors cite a lack of opportunity available for teachers in primary schools in the UK to focus on group practical activities in science as one possible reason for this perception.

Studies conducted mainly in the UK and USA present convincing evidence that young people develop stereotypical images of science and scientists from an early age. These images are markedly persistent, regardless of the best efforts of curriculum developers and teachers. Findings suggest a need for continued exploration of effective ways to portray science and scientists in realistic ways, to counteract the powerful images and impressions from television, books, films, etc. Possible areas for development include science resources and materials used in primary schools that present realistic images of science and scientists, including videos and interactive computer software; intervention programmes for older pupils to reinforce positive images of science and scientists, through group work during science lessons, designed specifically to demonstrate the collaborative and cooperative nature of many science-related careers; and topics and activities in science lessons that help pupils make connections between school science and its applications in everyday life.

What factors influence attitudes toward science?

There are a number of factors influencing young people's attitudes toward science. Studies of attitude toward science among young people tend to focus on the relationship between attitude and one or more associated factors.

Classroom environment

The influence of classroom environment on young people's attitudes to science has long been recognised as significant by researchers, particularly in Australia and the USA (Moos, 1979; Fraser, 1982; Fisher and Fraser, 1983; Fraser, 1986), where studies mainly utilised the Learning Environment Inventory, devised by Walberg (1969), to investigate inconsistencies in teachers' and young people's perceptions of the classroom environment and discrepancies between young people's preferred and actual environment. These studies produced conclusive evidence that teachers had considerably more positive perceptions of science classroom environments than did their students who were, on the whole, dissatisfied. Myers and Fouts (1992) provided perhaps the clearest insight into student preferences in their quantitative survey of 699 high school students in the USA, where it was found that students demonstrated most positive attitudes in science classes where a high level of personal involvement was actively encouraged by teachers using a range of instructional strategies to deliver a variety of stimulating activities, alongside a high level of support for individual students and strong peer relationships.

These findings are supported by those of other studies analysed for this review (e.g. Haladyna *et al.,* 1922; Henderson *et al.,* 1998; Talton and Simpson, 1987), including Simpson and Oliver's (1990) longitudinal study of attitude toward science, motivation and self-concept in science. Results highlighted the strong influence exerted by science classroom variables on adolescents' attitudes toward science. The authors concluded that "…the basic feelings an adolescent formulates toward science and toward future involvement with science courses is in large measure mediated by the science classroom" (p.13).

The majority of studies conducted in this area have utilised quantitative methodology and focused on pupils in secondary schools. One notable exception is the qualitative research study of Piburn and Baker (1993), which explored the importance of classroom environment for 149 students from elementary, junior high and high schools in the USA. Open-ended interview questions were designed to assess changes in attitudes and to identify factors affecting individual attitudes toward science. The findings provided conclusive evidence that younger students enjoyed 'action oriented' and 'open-ended' activities that helped them 'learn about the workings of their world' (p. 402); whereas from junior high to upper high school students became increasingly uncomfortable with open-ended activities as they were unhappy at the idea of being held accountable for work where the outcome had not been clearly specified, preferring the greater certainty contained in textbooks and worksheets. The least positive attitudes were found among high school students, many of whom claimed no longer to understand science due to the growing abstraction and complexity associated with science, coupled with a view that science was not relevant to their lives. They no longer enjoyed science and would not pursue it any longer, nor consider it as a career option.

Teacher influences

It is clear from studies conducted over the past 30 years that classroom environment is inextricably linked to issues of effective pedagogy. As Ebenezer and Zoller (1993) found in their study involving 1564 grade 10 (15 to 16 years) students, "the most important variable that affected students' attitudes toward science was the kind of science teaching that they experienced" (p. 182); a finding confirmed by Haladyna *et al.* (1982) who explored the attitudes of 1965 young people between the ages of 10 and 15 years. While correlations between perceived quality of teaching and students' attitudes to science were low for boys and girls in the lower age range, high correlations were reported at the ninth grade (13 years) for boys and girls. However, a note of caution must be sounded here as the authors accepted that the precise criteria applied by students in identifying the quality teaching across the age ranges are unclear, with data perhaps arising from a change in definition of quality teaching as individuals progress from a junior, largely self-contained classroom environment to a subject specific science classroom in high school. An alternative explanation is a possible change in students' expectations; they may "become more discriminating with grade level as they apply a consistent criterion to the quality of teaching" (p. 680). Whatever the explanation, this is clearly an aspect of changing attitudes to the teaching of science that warrants further investigation.

While the majority of remaining studies analysed for this review tended to focus on young people in secondary education, one exception was the recent work of Den Brok *et al.* (2005) in Brunei, which explored the attitudes of 1305 primary-aged pupils in 64 classes toward teachers' interpersonal behaviour in science. Utilising the *Questionnaire on Teacher Interaction*, devised for the study, pupils were asked to comment on eight aspects of teacher interpersonal behaviour, including *leadership qualities; helpful/friendly; giving students freedom and responsibility; uncertain; dissatisfied; admonishing and strict.* The authors reported strong and positive effects of teacher influence and proximity on pupils' enjoyment of science, though they acknowledged difficulties in applying their findings more generally, as the focus was firmly on *enjoyment* of science, with no consideration given to attitudinal concepts such as interest, confidence, self-image and relevancy of science for individual students. Despite the somewhat narrow focus of the study, it provides some insight into attitudes among younger pupils and should go some way towards raising the awareness of teachers of the effects of their behaviour on students' attitudes to science, thus offering opportunities for changes in practice.

What is largely missing from this aspect of research is any clear idea of the nature of instructional strategies, or teaching styles that positively enhance young people's attitudes to science. The reason for this is that studies are mostly quantitative, involving the use of questionnaires with predetermined statements for young people to rate or respond to in writing. For example, one questionnaire developed by Ebenezer and Zoller (1993) asked students to rate on a five-point scale statements such as:

- We watched our teacher do experiments in science.
- The teacher handed out notes in science.
- We copied the teacher's notes from the blackboard or overhead. projector to our own notebooks in science.

- We worked in small groups.
- We did experiments in science individually (without any lab partners).

While great care is clearly taken in identifying relevant statements for such studies, these aspects of teaching and learning in science did not originate from the students themselves. It might therefore be argued that questions concerning the criteria individual students apply in responding to such statements are inevitable. A further difficulty arises in attempting to find patterns in young people's attitudes to variables such as teaching styles and instructional strategies due to differences in the instruments used to measure and assess attitudes. For instance, while Ebenezer and Zoller (1993), quoted above, utilised the *British Columbia Science Assessment Inventory* (Bateson *et al.,* 1986), a similar, earlier study into the relationship between teacher and student and learning environment by Haladyna *et al.* (1982) utilised the *Learning Environment Inventory* and the related *My Class Inventory* (Walberg, 1969), with very different statements to be rated, for example:

- teacher enthusiasm
- respect for teacher
- teacher support for the individual
- teacher praise and reinforcement
- teacher commitment to learning
- fairness.

Although there is no reason to suppose that findings from either study lack validity and/or reliability, it is impossible to form a view of common factors in teaching styles and instructional strategies from such diverse data. Perhaps the most helpful study in identifying key features of quality teaching was conducted by Woolnough (1990) and utilised both quantitative and qualitative methodology in a comparative study of the attitudes toward science of students in England who had chosen to study science at A level and those who had not. A total of 1180 sixth form students completed questionnaires and a further 108 students and 84 staff from 12 schools were interviewed. Of the six factors identified as informing student subject choice, the two strongest were individual experience of extra-curricular activities and the quality of teaching. Analysis of questionnaire and interview data enabled Woolnough to identify the following attributes of a good science teacher:

- enthusiasm for their subject
- setting lessons in everyday contexts
- managing well ordered and stimulating science lessons
- were sympathetic and demonstrated a willingness to support students individually both during and outside science lessons
- were willing to discuss career options with students.

These attributes reflect those identified by Eichinger (1997) in his study of 210 first-year US college students, aged 16 to 21 years. Questionnaires encouraged students to reflect on their school science experiences in junior high and high school and the responses of successful college science students (114) were compared with those of successful non-science students (87).

Particular emphasis was placed on recollections of teacher personality attributes and instructional strategies. Findings indicated a preference among science students for teachers who were *knowledgeable; enthusiastic; communicative; committed; friendly; competent* and *creative*, while non-science students preferred teachers who were *patient; knowledgeable; congenial; friendly; supportive* and *enthusiastic*. While school science for both groups had been dominated by textbooks and taught lessons, they all expressed a preference for more dynamic approaches to science, including laboratory activities, teacher demonstrations and discussions. The findings of this study support Tobias's (1990) conclusion that "…a large number of American high school graduates survive their less than perfect pre-college education with their taste and even some talent for science intact" (p. 8).

However, Koballa (1985) would argue that 'survival' is not enough. He rejected as no longer valid an apparent assumption among science educators that students would "acquire positive attitudes toward science as they learn more science facts" (p. 222). In his view, teaching programmes/schemes of work should include planning for the development of positive attitudes to science, as a failure to do so may result in a science curriculum that fails to prepare young people to make subject choices and career decisions later. Although Koballa offered little practical guidance to inform such planning, he acknowledged the importance of teacher understanding of the nature of attitudes towards science, in changing practice. Taking a somewhat different stance, Woolnough (1990) maintained that many instructional strategies identified by secondary school students as positive influences on their attitudes to science would be achieved if teachers were allowed to teach in their specialist science area, where they are likely to feel most confident and thus teach with the greatest enthusiasm.

Findings show that classroom environment and perceived quality of teaching are influential in informing attitudes toward science among young people. While studies reported here make a convincing argument for a supportive classroom environment that is also stimulating, encourages student involvement and promotes collaboration among students, the nature of effective instructional strategies to enhance attitudes toward science is less clear. Although the qualitative aspects of Woolnough's (1990) study were helpful in identifying distinguishing features of quality teaching, students were responding retrospectively, affording little insight into how or why perceptions of effective teaching might change over time. In considering possible reasons for the decline in perceptions of quality teaching from primary to secondary school, it might be necessary to explore the relationship between teaching and influences of other variables, such as the increasing complexity and abstraction of the science curriculum on the attitudes of young people toward science.

The findings reported here make a convincing case for the importance of teacher influence on young people's attitudes toward science, but there is a need for more in-depth exploration of the attributes of quality teaching, possibly utilising qualitative methodology in combination with questionnaire surveys.

Parental influence

While there have been many studies undertaken in the USA about parent involvement in their children's education generally and the effect of such involvement on individual levels of achievement in science (George and Kaplan, 1997), limited research has been conducted on possible influences of parental involvement on attitudes to science. Exceptions include the work of Schibeci (1989), who explored a range of influences including home, school and peer group on attitudes toward and achievement in science among Australian high school students. He found the influence of mothers to be more significant for achievement than attitudes toward science. However, the findings of a similar study conducted by George and Kaplan (1995) in the USA identified a moderate correlation between parental involvement and attitudes toward science. In a later study by the same authors (George and Kaplan, 1997), in which they utilised data from the National Educational Longitudinal Study (NELS) of 1988 to identify the extent of parental influences on eighth-grade students' (aged 12 years) attitudes toward science, the findings showed clear evidence that parents played an important role in the development of science attitudes among young people, particularly through their involvement in hands-on science-related activities such as library and museum visits.

Disagreement persists concerning the strength of parental influence on young people's subject choices post-16. Papanastasiou and Zembylas (2002), claimed that the extent to which home background and parental influence on attitude and achievement was uncertain. George (2000), in her continuing work in this area, reached a similar conclusion in stating the parental variable to be insignificant among her sample of whole year groups of high school pupils. However, Cleaves (2005) in her three-year study involving subject choice decisions among 72 able students, found parents to have a significant profile in advising and guiding their children's choices of subjects post-16.

Peer influence

Peer pressure was found by Shrigley (1983) to be one of the main examples of social influence on adolescents. George (2000) went so far as to suggest that attitudes toward science among peers are even more influential than the attitudes of parents or teachers. Talton and Simpson (1986) identified a strong correlation between individual and peer attitude toward science, particularly in grades 6, 7 and 8 (11, 12 and 13 year olds), but peaking at the beginning of grade 9 (14 year olds). However, Atwater *et al.* (1995) in their study of attitudes among 1413 African-American students, found that students in grades 6, 7 and 8 believed themselves to have more positive attitudes towards science generally than their friends. Schibeci (1989), in his study of attitudes among grade 8 students in Australia, found no effect of peer influence on attitudes.

The lack of conclusive evidence concerning the influence of peer groups on attitudes toward science might be the result of a lack of clearly defined, and/or consistent measures of peer attitudes or peer influence, suggesting there is much scope for further investigation in this area.

Influence of culture and ethnicity

Few studies have focused specifically on issues of culture and ethnicity in relation to attitudes toward science. The extent to which the relationship between ethnicity and attitudes might be significant is far from certain.

Rennie and Dunne (1994) found no correlation between ethnicity and attitude toward science among 16-year-old students in their study of perceptions of science and career choices of students in Fiji, though studies of subject choice among African-American students (Atwater, 1986; Atwater and Simpson, 1984; Atwater *et al.,* 1995; Goggins and Lindbeck, 1986) have consistently shown that students from this ethnic group do not pursue science-related courses or careers. Factors such as parental and family influences are highlighted as possible reasons, though there is no conclusive evidence to support this. Atwater *et al.* (1995) identified individual characteristics such as self-concept and achievement motivation in science, as well as attitudes toward science as reasons for reluctance on the part of African Americans to pursue science courses post-16. Additional factors such as attitudes toward class climate and teachers are thought to inform course choice and career decisions among African Americans. Greenfield's (1995) survey of career intentions among approximately 1000 American students in grades 3, 6, 8 and 10 showed a correlation between ethnic origin and attitudes toward science and science-related careers that was found to be more significant than correlations between gender and attitude toward science. While Caucasians expressed the most positive attitudes toward science, Japanese Americans were found to be most positively disposed toward science-related careers.

Although evidence from the literature is far from conclusive, emerging from these studies is a clear indication that within some cultural/ethnic groups there is a tradition of non-involvement in science and science-related careers. If science is to reflect the society it represents, then this is an issue of immediate concern for science educators.

Influence of gender

Gardner (1995) maintained that gender was probably the most significant variable related to young people's attitudes toward science, a view borne out by the considerable interest of researchers in this aspect of attitudes toward science among young people. Much of the research in this area has been conducted with young people in secondary schools, with few studies focusing on gender differences among younger pupils.

The predominant message from researchers in the UK, Australia, the USA and elsewhere is that boys have consistently more positive attitudes toward school science than girls at the level of secondary education (Breakwell and Beardsell, 1992; Engström and Noonan, 1990; Erickson and Erickson, 1984; Greenfield, 1997; Hendley *et al.,* 1996; Johnson, 1987; Smail and Kelly, 1984).

A good example of differences between girls' and boys' attitudes toward science is provided by Hendley *et al.* (1996) and Parkinson *et al.* (1998), whose large study investigated attitudes toward school science among 1038 Key Stage 3 pupils (aged 11 to 14 years) in South Wales, following the implementation of the National Curriculum. Complementary research methods were utilised, including a 34-item questionnaire, followed by structured interviews with a representative sample of pupils. The findings confirmed those of others in reporting pupils' awareness of the importance of studying science in school (Ebenezer and Zoller; Osborne *et al.,* 2003; Osborne and Collins, 2000; Reiss, 2004).

Parkinson *et al.* (1998) showed that overall boys and girls had positive attitudes toward school science in Key Stage 3, though in five of the six factors found in analysis, including *enjoyment; level of difficulty, importance, reading and writing, practical* and *time,* boys had significantly more positive attitudes than girls, the exception being the *importance of science* where no significant differences were detected. Involvement in practical activities was found to be a significant factor in promoting positive attitudes toward science for both boys and girls, particularly in chemistry, which was found to be the most popular of the three sciences as it was closely linked to practical work in science lessons. An interesting finding emerged from a parallel study of 250 year-11 pupils (aged 15 years) in South Wales (Hendley *et al.,*1996), where the greatest antipathy was expressed toward chemistry, seen to be abstruse and irrelevant to pupils' lives, but, on the other hand, was enjoyable when practical work involved mixing and combining chemicals.

A small number of studies (Johnson and Murphy, 1986; Johnson, 1987; Kahle and Lakes, 1983; Kahle *et al.,* 1985; Osborne and Collins 2000; Rennie, 1987; Taber, 1992; Thomas, 1986) have identified a direct relationship between pupils' interests and experiences outside school and attitudes toward school science. Girls are less likely than boys to engage in leisure activities involving a variety of mechanical and technological devices. Parkinson *et al.* (1998) expressed disappointment at the small number of science-related hobbies and out-of-school activities of pupils generally, particularly given the extensive range of activities and resources freely available for young people today. It has been shown that girls tend to enjoy and are more proficient readers than boys (Gorman, 1992), a claim borne out by Parkinson, who reported more positive responses from girls than boys to reading and written aspects of Key Stage 3 science.

The majority of studies of gender differences in science education focus on older pupils. One notable exception is a longitudinal study, part of two large attitude surveys undertaken as part of the Girls into Science and Technology (GIST) project and conducted by Kelly (1986), who explored the development of attitudes toward science among boys and girls during their final year of primary education and two years of secondary education. Pupils' attitudes toward science were found to decline markedly between the ages of 11 and 13 or 14 years, as did their view of the importance of science in society and their images of scientists. Personal enjoyment of science also declined, especially among girls, though they became less likely to see science as exclusively a boys' subject as they got older. Interest in most aspects of science appears to have declined sharply among boys and girls. However, the exception to this general deterioration in attitudes toward science was noted in marked improvements in interest in human biology, particularly among girls. Kelly concludes that there is no short answer to the general decline in pupils' attitudes during their move from primary to secondary education, though she believes it to be a sad reflection on science teaching in this country.

To explain possible reasons for gender differences, a range of variables are discussed in the literature. Studies examine the materials and resources used in science, such as computer software, textbooks and classroom displays that are said to exhibit gender bias with content and activities more appealing to boys than girls (Bazler and Simonis, 1991; Jones and Wheatley, 1989; Warren and Rogers, 1988). The role of the teacher in science lessons is thought by some researchers to be linked to gender differences in attitudes toward science. A number of studies have shown that boys in science classrooms tend to receive more attention from teachers than do girls. Boys are called on more frequently to answer questions; they tend to receive more detailed feedback on questions and on their work, and they are given greater freedom to contribute to discussions without being called upon to do so (Kahle and Lakes, 1983; Kahle and Meece, 1994; Sadker and Sadker, 1994).

There is a suggestion that science classrooms can reinforce masculine stereotypes of science (Kelly, 1985; Whyte, 1984) and this led some researchers to explore attitudes among girls and boys in single-sex and co-educational schools (for example, Ato and Wilkinson, 1983; Colley *et al.*, 1994; Harvey and Stables, 1986;). The notion that single-sex schools showed less sex stereotyping than co-educational schools in relation to subject choice, was first mooted by Ormerod (1979), and explored in some depth since by others (e.g. Harvey, 1985; Deem, 1984; EOC, 1981; Stables, 1990). The argument rests on the premise that if the language of the science classroom, topics studied, forms of discipline, methods of encouragement and criticism, and teaching and learning materials are oriented more towards boys than to girls, then it would be beneficial for girls to be taught in separate classes (Marland, 1983). Harvey (1985), in his study of single-sex science teaching in a mixed school, reported no gains in achievement or improvements in attitudes toward science among first-year secondary school girls or boys, though the author conceded that it was likely to take more than the one year of the study before positive results might be achieved.

In a later study Harvey and Stables (1986) and Stables (1990), investigated in more depth the attitudes toward science of 2300 third-year (aged 14 years) pupils in seven mixed, three all-boys and three all-girls schools in England. Findings showed that girls taught in all-girls school demonstrated more positive attitudes toward the physical sciences, though the attitudes of boys towards physical sciences were unaffected by the nature of the groups in which they were taught. However, in biology it was found that girls taught in mixed groups had significantly more positive attitudes than girls in single-sex groups, whereas boys showed more positive attitudes in single-sex groupings. The authors concluded that if the attitudes of girls toward science are to be addressed, a case might be made for single-sex grouping for physics and chemistry, but not for biology.

The study conducted by Ato and Wilkinson (1983), with 1430 12- to 16-year-old students in mixed, all-boys and all-girls schools in Nigeria, shows some important similarities, but raises another issue in relation to the type of school attended by students. They found that girls in single-sex schools showed more positive attitudes toward science than girls in mixed schools. It was also found that school type was of greater importance to girls than boys, thus attitudes toward science might simply be a reflection of a generally more positive attitude among girls in single-sex schools. While boys showed consistently more positive attitudes toward all sciences than girls, school location was an important issue for boys, though in their case, those attending rural schools had more positive attitudes than those attending urban schools, regardless of school type. The influence of school type and location is a variable not found in any other study, therefore it is worthy of consideration in any future research in this area.

There is some disagreement in the literature about the relationship between gender, attitudes toward science and desire to pursue a science-related career. There are those who would argue that secondary school students hold firmly rooted stereotypical ideas about the appropriateness of certain careers for men and women, including science-related careers (Mason and Kahle, 1988; Taber, 1992). Others argue that evidence is emerging to show that girls no longer have such strongly held stereotypical views of careers in science, expressing confidence in their ability in science (Colley *et al.,* 1994; Havard, 1996; Lightbody and Durndell, 1996; Whitehead, 1996). Archer (1992) reported findings from a study of subject preferences among girls aged 10 to 15 years, which showed a strong liking for the stereotypically masculine subjects of science, mathematics and sport studies.

In terms of the relationship between gender, attitude and achievement (Department for Education and Employment, 1997) figures for 1996 examination results for science showed there was little difference between the attainment of boys and girls in science at GCSE level in England. More recent figures, detailing 2004 GCSE science results showed that girls did better than boys in biology and chemistry at A-C grades, but boys achieved higher scores in physics A-C grades (JCQ, 2005).

It is clear that achievement in science is not an issue in informing girls' course and career decisions. What remains a mystery is *why* girls choose not to pursue science courses beyond the age of 16 years, leading to science-related careers. Kelly (1988) offered the simple explanation that though girls might have positive attitudes toward science and express confidence in their ability, they may simply find other subjects more appealing. Although she does not explain why this might be the case, her findings showed a strong correlation between liking a subject and course and career decisions. Some further insight is provided by Whitehead (1996), whose study of 'feminine' and 'masculine' subject choices among 342 girls and boys respectively at A level in the UK, found that, while gender differences were apparent in students' views of subjects, boys exhibited greater bias in subject choices, with those choosing 'masculine' subjects more likely to support traditional sex roles. Whitehead offers an interesting conclusion in suggesting that girls are not under-represented in physics and chemistry, it is boys who are over-represented as they tend to be motivated in subject choice by a desire to pursue careers of high status that are highly paid.

Discussing issues of stereotypical views of the sciences among adolescents, Lightbody *et al.* (1996) argued that the important issue was not whether science and technology were viewed by pupils as ‘masculine’ subjects and careers, but that the content of much of the current physical sciences curriculum, with its emphasis on technological issues, is of less interest to girls than to boys. They recommended a review of the physical sciences curriculum and approaches to teaching and learning in these areas, to make them more appealing for girls, as a greater focus on people and society is thought to be the key to increasing the choice of physical sciences among girls.

It remains the case that boys exhibit consistently more positive attitudes toward science generally than do girls. However, optimistic signs emerging from the literature indicated positive attitudes among secondary school girls for biology and in particular human biology. Questions concerning the extent to which single-sex schools or science classes influence girls’ attitudes toward science remain largely unanswered, though findings suggesting positive improvements in the attitudes of girls taught in separate classes for physics and chemistry warrant further investigation. There is convincing evidence to show that girls do well in examinations in science and are less influenced by stereotypical images of science as a masculine career, so the question of what is turning girls away from science remains for further exploration.

Can attitudes be improved through intervention programmes?

One criticism levelled at much research into young people’s attitudes to science is the lack of explicit, or even implicit, recommendations for teaching that might help to improve attitudes to science. Studies focusing on the influence of new curriculum materials or instructional techniques in improving young people’s attitudes toward science go some way to addressing this issue.

Much of the research in this area has been carried out in the USA where studies tend to be conducted in one of two ways. First, intervention lessons or programmes, are devised and presented to an ‘experimental group’, while a ‘control group’ continues with the existing curriculum materials/input for the topic (Eisen *et al.*, 1986; Houtz, 1995; Lowery *et al.,* 1980; Stratford and Finkel, 1996; Gibson and Chase, 2002; Brossard *et al.,* 2005; Cepni *et al.,* 2006). A useful example of this model is a study conducted by Sinclair (1994) to investigate the effects on learning, motivation, attitude, classroom participation and critical thinking among 179 high-school biology students in the USA. Comparisons were made between experimental-treatment groups of students involved in an intervention programme focusing on the use of critical thinking and prediction activities in the teaching and learning of genetics concepts in biology, and control groups who were taught the same topics, by the same teachers, using traditional teaching methods and activities. Data were collected using quantitative measures of *genetics achievement; achievement motivation* and *attitudes toward science*, together with qualitative methods, including *classroom observation* and *interviews*. Results showed no significant differences between the experimental and control group on attitudes toward science as a result of intervention, though qualitative data analysis showed a significant correlation between achievement motivation and attitude toward science in the experimental group. This led the author to conclude that increased involvement of students in the experimental group positively enhanced motivation, which in turn had positive effects on attitudes toward science.

The second approach eschews the use of control groups, preferring to instigate programmes of instruction using pre- and post-tests to assess changes in students' knowledge of and attitudes toward specific aspects of science (Arch, 1995; Boone and Edson, 1994; Caleon and Subramaniam, 2005; Dawson and Taylor, 2000; Freedman, 1997; Kelly, 1988; Showers and Shrigley, 1995). A useful example of this approach is the study conducted by Bradley *et al.* (1999) in which the knowledge of and attitudes toward environmental science of students from 18 high schools enrolled in the environmental science course *Agriscience 384* were assessed. The course comprised four sections and took ten, 50-minute periods over ten days. Teachers were supplied with guides and all necessary materials to ensure the course was delivered in the same way across the schools. Students' environmental knowledge and attitudes were assessed with pre- and post-tests, the pre-test acting as the control group. The same attitude instrument was used as part of both tests, with an inventory comprising 15 questions to be rated on a Likert type five-point scale. Findings showed a significant correlation between attitudes toward science and knowledge in this area of environmental science, with increases in knowledge scores and more positive attitudes demonstrated by students. These findings are supported by Armstrong and Impara (1991), who also reported moderate to strong correlations between environmental knowledge and attitudes of students participating in programmes lasting between four and eight weeks.

What is evident among intervention studies is the lack of conclusive or significant findings on attitudes to science. Brossard *et al.* (2005) recognised this in reporting the findings of an environmental science intervention programme where no statistically significant change was found in participants' attitudes toward science, attitudes toward environment or understanding of the scientific process could be detected. In the light of these results the authors suggested that intervention projects must make explicit to participants the issues they are expected to consider and the scientific processes in which they are to engage if responses are to offer insight into individual attitudes toward science. They also suggested the need for qualitative methodology, including interviews with selected individuals to validate rated statements and multiple-choice responses, to provide greater insight into reasons for the findings.

Koballa (1985) expressed serious reservations about some intervention programmes, maintaining that all but a few devised to improve students' attitudes toward science ”lacked any semblance of a theoretical basis” (p. 223). He maintained that interventions such as ”enrolment in semester-long science courses, or traditional versus innovative curricula seem to have added little understanding to what is known about changing attitudes toward science” (p. 223). The findings of our analysis of the literature would lend some weight to this argument. While each intervention appeared to have at least some merit, it was impossible to judge the relative efficacy of intervention programmes in improving attitudes toward science, particularly in the case of studies that relied on experimental and control groups where the content, concepts and delivery of science were not articulated and were not analysed.

What is missing from the literature in this area is any sense of follow-up, or longer-term studies that might seek to assess the extent to which interventions were effective in changing students' attitudes toward science in the longer term, for instance, by influencing course choice, career aspirations, etc. Analysis of a considerable number of intervention studies for this review leads to the conclusion that intervention programmes are more likely to have positive short-term effects on achievement and knowledge gains than on attitudes toward science (e.g. Freedman, 1997; Cepni *et al.,* 2006). However, a note of caution needs to be sounded here, as knowledge gains are typically measured using post-tests immediately following intervention; we therefore have only limited knowledge about the extent to which longer-term knowledge gains have been achieved as a result of such interventions.

Relationship between attitude and achievement

The body of research exploring the relationship between attitudes toward and achievement in science has been fairly extensive, particularly in the USA. However, the strength of the relationship, or its significance for student subject choice or career decisions, is still open to debate.

Many research studies and reviews of literature since 1980 have identified a relationship between attitude and achievement (House, 1993; House, 1996; Oliver and Simpson, 1988; Schibeci and Riley, 1986; Weinburgh, 1995), but few have attempted to explain the relatively low correlations reported in these studies between attitude and achievement. Rennie and Punch (1990) blamed a lack of theoretical framework to facilitate an exploration of the relationship between achievement and attitude, though it has been argued that the relationship between attitude and achievement is a complex one, in which multiple variables apply, including perceived level of difficulty in studying science, influences of teaching strategies and/or influences outside school (Osborne *et al.,* 2003).

One study where a correlation was found and reported by Papanastasiou and Zembylas (2002) and Papanastasiou and Papanastasiou (2004) involved students taking advanced science classes at high-school level in Cyprus. The country was selected because it had adopted ideas for the education system from the USA, UK and Greece. While correlations between achievement and attitude were moderate, the authors concluded that attitudes toward science influenced achievement, but achievement in science does not necessarily guarantee more positive attitudes among boys or girls. The home background of students was found to have some influence on attitudes and achievement, but the degree to which this was a significant factor remained uncertain.

A longitudinal study conducted in the USA, involving 4500 students from grades 6 to 10 (11 to 14 years), has a useful contribution to make to an understanding of the relationship between attitude and achievement (Oliver and Simpson, 1988; Simpson and Oliver, 1985; 1990; Simpson and Troost, 1982). Their study was influenced by Bloom's (1976) assertion that 25 per cent of variance in school achievement could be attributed to the way individual students felt about what they were learning, their school environment and their concepts of self. This led to an exploration of the relationship between three independent variables: *attitude toward science; motivation to succeed in science* (termed *achievement motivation);* and *self-concept in science.* Findings showed a strong relationship between the three variables, with a steady decline in attitudes toward science from grade 6 to grade 10, a corresponding decline in achievement motivation. Decline in achievement motivation was more significant among boys than girls. A strong correlation was found between self-concept in science and attitudes toward science generally for boys and girls. At the end of the study, students in grade 10 exhibited near neutral achievement motivation and attitudes toward science, with a significant majority electing to pursue subjects other than science at senior high school.

The strong relationships found between the three variables in this study may be attributable to a focus on motivation rather than attitudes toward science. It raises questions concerning the extent to which motivation to achieve in science might be a stronger indicator of attitudes than actual achievement in science. One interesting aspect of this study centres on findings showing that girls exhibited stronger achievement motivation in science than boys. This may go some way toward explaining why the results achieved by girls in GCSE science examinations are generally higher than boys, though they exhibit consistently less positive attitudes towards science.

A lack of conclusive evidence to show a strong correlation between attitudes toward science and achievement in science signals a need for further research and, in light of findings from the study by Simpson and Oliver (1990) discussed above, a case might be made for more in-depth investigation of the relationship between motivation to learn science and attitudes toward science.

Changing attitudes over time: cross-sectional and longitudinal studies

The dearth of longitudinal studies of young people's attitudes to science is disappointing. Such studies facilitate the tracking of changes in attitude over time, an important consideration for research because the measurement of change in individual attitudes over time "allows one to document each person's progress and, consequently, to evaluate the effectiveness of educational systems" (Willett, 1994; p. 671).

The majority of studies analysed for this review were cross-sectional rather than longitudinal, meaning they could not explore changes in or stability of individual attitudes over time. The more common practice of assessing changes in attitudes toward science over time is to involve young people from a range of year groups and to compare rated responses according to age. One advantage of such research is that a lot of data can be gathered in a relatively short time, compared with the length of time required to track the same cohort of pupils through several years. One drawback however, is that it makes the assumption that changes in attitudes toward science are age-related. This is a somewhat simplistic assumption that fails to take account of individual differences, individual perceptions of science and the ways in which these might develop and change over time as a result of personal experiences, both within and outside school.

Most of the longitudinal studies analysed for this review have focused on the erosion of young people's attitudes toward science over time, usually during the first three or four years of secondary education (Kelly, 1986; Hadden and Johnstone, 1983, 1983a, 1983b; Reiss, 1994; Simpson and Oliver, 1990; Speering and Rennie, 1996). Embedded in much of this literature is an assumption that younger pupils in primary/elementary schools have generally positive attitudes toward science, and erosion begins once they enter secondary/junior high school. However, a UK study conducted by Murphy and Beggs (2003), of changing attitudes among 1000 pupils between the ages of 8 and 11 years (Key Stage 2; year 3 to year 6), found that the decline in attitudes began much earlier and pupils had already begun to exhibit negative responses to some aspects of science before they left primary school. The results showed that most 10 to 11 year olds had significantly less positive attitudes toward science than 8 to 10 year olds, even though older pupils exhibited greater confidence in their ability to do science. The authors ponder whether this erosion of attitudes toward science is simply a reflection of deterioration in attitudes toward school more generally, a reasonable question given the inevitable preparation for national tests at the end of Key Stage 2. Citing findings of other studies, conducted in the USA, they conclude this to be unlikely, though the question of why attitudes toward science decline in the final years of primary school remains unanswered and warrants further investigation.

A study of changing attitudes among pupils during the period of transition from primary to secondary school, conducted in Scotland by Hadden and Johnstone (1982; 1983a; 1983b), provided further insight into when attitudes toward science begin to change. The study utilised complementary methodology including attitude questionnaires and semi-structured interviews to explore attitudes toward science among over 1000 11-year-old primary school pupils prior to transfer to secondary schools. Findings showed a high degree of interest in and enthusiasm for science among pupils immediately prior to their transfer to secondary school. Towards the end of the following year (1983a), the same attitude questionnaires were administered to the same pupils (aged 12 years). Although some erosion of initially highly favourable attitudes toward science had occurred – and was more pronounced than for mathematics or geography – evidence found attitudes toward science to be moderately favourable.

The final phase of the study (1983b) explored factors influencing pupils' subject choices at the beginning of their third year (14 years old) in secondary school. While the authors recognised that many factors influenced pupils' decisions at this stage of their education, attitude toward subjects was thought to be a significant deciding factor. Evidence showed that deterioration in attitudes toward science had continued through the pupils' second year of secondary education. However, this did not signal a complete reversal of originally positive attitudes, as pupils within the sample chose to pursue a range of science subjects in greater numbers than predicted by national figures for Scotland at the time of the research. The authors made an important point in relation to the use of quantitative methodology in exploring attitudes toward science in conceding that though they were confident of the validity of their finding, changes in attitude had been considerably easier to detect than factors that might account for such changes. Differences in modes of learning and attitudes toward science among pupils from different schools emerged during analysis. While no specific reasons for this emerged from data, the authors suggested that such differences may be merely symptomatic of a more dominant factor concerned with pupils' views of science departments and teachers, as it had been found that where pupils described well organised science departments, with a secure learning environment, attitudes toward science were significantly more positive.

Similar conclusions were reached by Kelly (1986) in her two-and-a-half year study – part of the larger Girls into Science and Technology (GIST) intervention project – of attitude change among 1300 11 to 14 year olds in UK schools. Findings confirmed an overall decline in pupils' attitudes between the ages of 11 and 13 or 14 years. Pupils' interest in and enthusiasm for science waned, as did their desire to learn most aspects of the physical science featured in the curriculum during this period. However, the notable exception was human biology, where desire to learn increased markedly among boys as well as girls. Alongside these findings, Kelly identified quite marked differences in pupils' attitudes in different schools, though it was impossible to identify reasons why some schools were more successful than others in maintaining pupils' initially positive attitudes.

This raises some interesting questions, given the conclusions reached by Hadden and Johnstone, as the course of study underpinning the GIST research – designed to enhance the involvement and attitudes toward science and technology among girls – was devised by the research team and the teachers involved in the project were given special training in delivering the science content to ensure consistency of content and approach across schools. Clearly there is a need for detailed case-study work if reasons for differences in findings are to be explained, and this highlights the need for further in-depth investigation of pupils' responses and views of science course content and approaches to teaching.

Longitudinal studies of change in attitudes toward science of individual young people tend to be small in scale and qualitative in design. An example is a study conducted by Reiss (2004) to explore the experiences and changing attitudes toward science of four young people over the course of six years – from age 11 to 17 years. Results confirmed those of other research in showing that much of the enthusiasm demonstrated by each student in their first year of secondary education (age 11 years) steadily eroded during the next five years. Conclusions drawn from this study highlight the importance of the school science curriculum in influencing attitudes toward science, particularly the dominance of assessment for young people after the age of 14 years. During interviews, pupils commented on the lack of relevance to their lives of their learning in science and frequently found it difficult to recall topics learned in science. This led to the conclusion that "existing science curricula seem never to require students to reflect on *why* they are learning in science what they are learning…school science education is only likely to succeed when students believe that the science they are being taught is of genuine worth to them" (p.12).

The studies discussed here provide compelling evidence of a steady decline in young people's attitudes toward science over a relatively short period of time. The crucial time appears to be immediately prior to, or immediately following, pupils' transfer from primary to secondary school, suggesting that future research might establish possible reasons for a decline in attitudes toward science at that point. Further research is also needed if we are to understand more fully why once attitudes have begun to decline they continue to do so and what steps might be taken to reverse this seemingly inevitable process.

What is known about young people's attitudes toward biosciences?

Across the literature analysed for this review there is recognition of the dual purpose of science education. On the one hand the purpose is to provide pre-professional or pre-vocational training for future scientists, on the other hand to develop a scientifically literate public that has an understanding of issues such as global warming, ozone depletion, food safety, the genetic modification of organisms, etc. (AAAS, 1989; Millar, 1996; Osborne and Collins, 2000). Given the high level of interest and concern shown by researchers in this area, the dearth of studies focusing on young people's attitudes toward biomedical science, or biosciences in general, was surprising.

The studies of interest in this area focused on the teaching of controversial topics and ethical issues in biology, using intervention programmes to support teaching and learning (Van Rooy, 2000; Choi and Cho, 2002; Dawson and Taylor, 2000); an exploration of young people's understanding of genetics and genetic engineering (Lewis *et al.,* 1997; Wood-Robinson *et al.,* 2000; Hill *et al.,* 1999; 2000); students' knowledge of and attitudes toward biotechnology (Chen and Raffan, 1999) and young people's attitudes toward the use of animals for school science and scientific research (Silberstein and Tamir, 1981; Foster *et al.,* 1994; Millett and Lock, 1992; Stanisstreet *et al.,* 1993; Lock, 1995)

Haste's (2004) study of the beliefs and values held by 704 young people aged between 11 and 21 years in the UK found a moderate degree of qualified support among young people for developments in science though ethical issues were important, particularly among girls who exhibited positive attitudes toward science. Findings showed strong ethical concern towards animal welfare, an area identified by a number of research studies in recent years and one in which findings have been diverse. For instance, Haste's findings showed significant agreement among young people that the use of animals for experimentation was always wrong. This is in direct contrast to the findings of Hill *et al.* (1999), who reported strong support among 778 11- to 18-year-old

British students for the use of naturally bred animals such as mice and rats in medical research, provided no pain was caused. Millet and Lock (1992) and Lock (1995) revealed mixed views among the 460 14- to 15-year-old pupils surveyed, as they expressed generally anti-animal-use sentiments in relation to vivisection, except when related to life-saving medicines that had been tested on animals, for which the majority expressed strong support.

A slightly less morally contentious issue for young people in Haste's (2004) sample was the cloning of animals and the genetic modification of animals for medical research. Less than half expressed support for cloning and 30 per cent were unsure. One-fifth of students supported the genetic modification of animals for improved food production and 36 per cent were unsure. Genetic modification of plants was found to be the least morally contentious issue, though responses indicated that students considered this to be more a question of risk to health and the environment than an ethical issue. Over a third of students would support this as a benefit to the environment, and the same proportion would welcome nutritionally improved foods, though 23 per cent would not support it in either case and 37 per cent were unsure. Haste's survey provides useful insight into the views of young people on specific ethical dilemmas and moral issues in science. Perhaps the most revealing aspect of the findings is the broad spread of opinion among young people and the percentage that are unsure when faced with ethical decisions.

The views of younger pupils were sought in a survey of 433 11- to 12-year-old pupils in England (Stanisstreet *et al.,* 1993). The findings showed remarkably similar attitudes toward the use of animals for research as older pupils, with most objecting to the use of animals for clothing and vivisection, though many pupils were found to make a distinction between 'justifiable' vivisection – for medical research – and 'vivisection in general' (p. 424). Such surveys raise important questions about the extent of young people's knowledge and understanding of the issues about which their opinions are sought. This was recognised, in part, by Millett and Lock (1992), who argued for the inclusion of structured teaching and informed discussion of vivisection within the biology curriculum in Key Stage 4 (14 to 16 years old) to enable pupils to formulate informed and reasoned views and opinions on this and other ethical issues in scientific research.

Emerging clearly from these studies is a real sense of a willingness on the part of young people to engage with and express clear, strongly held views about scientific issues that have a direct relevance to their lives outside school. What is less apparent is the source of information that informs their views, particularly those of younger pupils in the UK, where the science curriculum touches only lightly on such issues as vivisection, genetic engineering, etc. Therefore, in analysing such studies, it is by no means obvious the extent to which pupils' views and attitudes toward biosciences are informed by secure knowledge and understanding. Perhaps in recognition of this, more recent research in this area has tended to assess young people's responses and attitudes toward controversial scientific issues following carefully structured intervention (Choi and Cho, 2002; Dawson and Taylor, 2000; Lewis *et al.,* 1997; Van Rooy, 2000; Wood-Robinson *et al.,* 1997; Wood-Robinson, 2000).

The need for intervention programmes to support assessment of young people's attitudes toward biosciences can perhaps be explained through the examples given in the literature that show a widespread lack of understanding of biotechnology among young people in the UK and Australia. In an early study, Lock and Miles (1993) explored the views of 188 16-year-old pupils to ascertain the extent of their knowledge of and attitudes toward biotechnology. Results showed that almost half the students (47 per cent) were unable to give an example of biotechnology and over half (52 per cent) were unable to give examples of genetic engineering. Where examples were given they included genetic fingerprinting and flower colour. Students expressed support for the use of genetically engineered micro-organisms in pharmaceuticals, but there was considerably less support for genetic engineering of farm animals.

Another UK study, Gunter *et al.* (1998), investigated the knowledge, perceptions and attitudes toward biotechnology, with particular reference to food production of 138 16- to 19-year-old pupils as part of a larger project conducted with the public at large. Results showed that while over half the sample of pupils involved in focus group interviews (N=48), had heard the term 'biotechnology', more than four in ten of those responding to the survey overall claimed not to have heard of the term. Where pupils were able to make associations with biotechnology, the most frequently mentioned applications were "production of crops capable of withstanding the use of pesticides without damage; cloning; and altering the genetic structure of bacteria" (p. 108). Focus group interviews were found to be useful in identifying aspects of biotechnology that young people found confusing. For example, many of them were said to associate biotechnology with mad cow disease, *E. coli* and other food safety issues, rather than genetic modification or cloning – a simplistic level of understanding found across studies in this area.

Chen and Raffan's (1990) survey of 183 Taiwanese and 153 British 16- to 18-year-old students also aimed to ascertain understanding of and attitudes to biotechnology. Results confirmed a limited understanding among students in both countries. Approximately half the students were able to give examples of biotechnology, though UK students gave more diverse examples, and approximately 60 per cent were able to give examples of genetic engineering. Attitudes toward biotechnology among students from both countries were markedly similar. In general, students were in favour of genetic engineering when applied to plants, but not to animals. Attitudes toward manipulation of organisms depended on the purpose; manipulation of organisms for disease resistance was acceptable, but unacceptable if used for enhanced growth. The authors conclude that positive attitudes to biotechnology are closely associated with sound biotechnology education. In short, informed students are likely to exhibit more positive attitudes and an open-minded approach to controversial issues in science.

Dawson and Taylor's (2000) study reports on the ability of year 10 (14 to 15 years old) Australian students to resolve bioethical dilemmas. On completion of specially designed biotechnology courses, introducing bioethics, students completed a survey in which they made a decision about three ethical dilemmas, providing reasons to support their decisions. The bioethical dilemmas centred on topics such as *cystic fibrosis; Huntington's disease; reproductive technology.* Students were presented with scenarios which focused on human dilemmas associated with each topic. Although findings showed some variation among students' responses, on the whole it was found that students tended to justify their decisions in way described by the authors as "naïve, individualistic and rights based" (p. 187). Teachers were advised to be aware that in resolving bioethical issues, students are likely to place an emphasis on the principle of autonomy, neglecting the importance of non-maleficence, justice and beneficence; therefore, learning activities need to be designed specifically to address this issue.

A sound example of this approach to assessing attitudes was found in a large study of young people's understanding of and attitudes to genetics and genetic engineering, conducted by a research team from Leeds University in the UK (Lewis *et al.,* 1997;). One part of this study, reported by Wood-Robinson *et al.* (1997), following their survey of 743 15- to 16-year-old pupils' understanding of gene technology and genetics, reported that over half the pupils (52 per cent) were unable to define genetic engineering, though over three-quarters (82 per cent) were able to give an example.

One smaller part of this study (Lewis *et al.,* 1997) featured a qualitative study to explore issues perceived by 60 15- to 16-year-old pupils as being raised by the application of new gene technologies and their opinions and attitudes concerning the application of such technologies. The intervention programme aimed to provide focused information about genetic engineering and a number of different applications. Individual understanding of genetic engineering, following intervention, was assessed through the use of a card sort activity, structured to elicit individual misconceptions. Students' views were sought on the issues raised in relation to gene technologies and their opinions and attitudes toward such topics as *human growth hormone; gene therapy; the oncomouse; scorpion venom pesticide; high-yield crops.* Results showed that young people used a wide range of criteria in deciding the issues raised in the use of genetic engineering, for example, *the relative value/importance of different organisms; purpose of use – medical, social, cosmetic/aesthetic, agricultural; is it needed/why is it needed/to what extent is it needed?* Students' attitudes to genetic engineering were summed up as:

- Things are as they are for a reason, so we shouldn't be trying to change them.
- Messing with genes is wrong; it is acting God; messing with nature.
- All organisms are not equal. (Bacteria and plants were considered less important than animals, and animals were considered less important than humans; the relative importance of different animals was often disputed.)
- Animals should not be made to suffer for the benefit of humans.
- It is only acceptable to use/change an organism/individual if it can give its consent. (It is wrong to choose the genes for another organism/individual.)
- If scientists can do it, they will and, if it is available, people will use it.
- Children should be loved for what they are.

In discussing the implications of these findings for science education, Lewis (1997) concludes that most young people of this age can, with the right materials and support, engage with complex scientific issues and form reasoned views. However, Lewis points out that an understanding of the concepts that underpin such issues, while desirable, did not appear to be essential in the decision-making process "…in most cases well reasoned discussion can take place without any reference to science" (p. 39), though she goes on say that, conversely, encouraging young people to discuss scientific issues which are relevant and interesting to them might stimulate an interest in the underlying science.

In a smaller study of attitudes toward ethical issues in science among 132 grade 8 (13- to 14-years-old) Korean students conducted by Choi and Cho (2002), experimental and control groups were used for their intervention programme. The experimental group followed a specially designed science course over 25 hours of class time, while the control group continued their usual led science lessons. Students' attitudes and achievement levels were assessed using pre- and post-tests. The intervention programme engaged in structured activities followed by guided discussion on a number of ethical themes including *cloning of human beings; genetically modified organisms; euthanasia; organ transplant and trading* and *use of animals for experiments.* The results showed that the teaching of ethical issues in science had a positive influence on students' attitudes toward science, particularly in raising interest in scientific issues and enhancing perceptions of the use of science in society. However, there was found to be no significant difference in achievement as a result of intervention, leading the authors to conclude that the existing science curriculum for grade 8 students was adequate to ensure achievement in science, though the addition of opportunities for students to explore ethical issues in science was strongly recommended to enhance attitudes toward science.

Studies reported here that utilised intervention programmes demonstrated the positive effects of such activities and courses on young people's attitudes toward bioscience. In considering studies undertaken without the use of intervention programmes, questions remained concerning the level of scientific knowledge and understanding that informed young people's responses to questionnaire items, particularly among younger pupils. There is a need to analyse school curricula in the UK and elsewhere, to ascertain levels of knowledge and understanding that might be expected among pupils of different ages, and to ascertain other sources of information about the biosciences available to and used by young people, before undertaking assessments of attitudes toward specific issues in the biosciences. Given the growing importance of scientific literacy and public understanding of science the findings of this review indicate an urgent need for focused studies of young people's knowledge and understanding of and attitudes towards issues that have an impact on the lives of every individual.

What can be learned from international comparative studies?

The Relevance of Science Education (ROSE) project implemented by Shreiner and Sjøberg (2004) is underpinned by a conviction that “science and technology are important parts of life in all countries, regardless of culture and level of material development” (p. 9). This international comparative project is designed to provide insight into factors related to attitude in learning science and technology among 15 year olds, to stimulate discussions about priorities and alternatives in science and technology education. Other large-scale comparative studies, such as the Third International Mathematics and Science Study (TIMSS) and the OECD Programme for International Assessment (PISA), provide information about performance and achievement among young people across the world.

There are significant differences, however, between TIMSS, PISA and ROSE. TIMSS tends to focus attention on “the curriculum as a broad and explanatory factor underlying student achievement” (Martin and Mullis, 2000, p. 30). In PISA the emphasis is on lifelong learning and “the extent to which education systems in the countries participating in the study prepare students to become lifelong learners and to play constructive roles as citizens in society” (Jenkins and Nelson, 2005, p. 42). In contrast to this, the smaller-scale ROSE project focuses on young people’s attitudes, interests and out-of-school experiences that are relevant to science and technology. The advantage of projects such as ROSE is the opportunity to explore attitudes and interests among young people in developing countries, a cohort largely excluded from the larger TIMSS and PISA. Such a project, with its emphasis on clear, unambiguous questionnaire design, is also capable of addressing some issues of inconsistency in research design across many international studies, which make it difficult to compare and contrast responses from young people in different parts of the world.

An example of one recent ROSE project, conducted in England by Jenkins and Nelson (2005) in 2003, formed part of a larger international comparative study based at the University of Oslo. The questionnaire survey of 1277 14 to 15 year olds focused on views about school science, what they would like to learn in school science classes and their career choices. Results suggested significant gender differences in general attitudes toward science, particularly in their views of the relative difficulty of school science. Responding to the statement that science was ‘rather easy to learn’, a significant percentage of girls tended to disagree strongly, while a significant percentage of boys tended to agree with the statement. More boys than girls thought science interesting and a subject that everybody should learn at school. However, a preference for other subjects over science was common to boys and girls.

While these findings offer no surprises, mirroring as they do a number of smaller studies analysed and discussed in this review, what is interesting is the similarities between responses among young people in this study and those of the same age reported in ROSE studies conducted in a number of other countries. In discussing findings from 22 countries, Sjøberg (2004) reported that in every study, science was found to be less popular than most other subjects, boys exhibited more positive attitudes toward science than girls, and in some countries, including England, girls exhibited a strong dislike for science. Exceptions were reported mainly in developing countries where young people's attitudes to science were generally considerably more positive (Sjøberg *et al.,* 2004). As Jenkins and Nelson (2005) made clear, the content of science curricula differ, in some cases quite considerably. Therefore, the findings intimate some common factors, perhaps "the nature of science, the way the sciences are taught, students' perceptions of the scientific disciplines, their experience of science, the structure of schooling or gender/social-based differences in cognition, aspiration and attitudes" (p. 51).

Jenkins and Nelson's (2005) study painted a fairly disappointing picture of the attitudes toward science of 14- to 15-year-old pupils following the national curriculum for science in England. Boys and girls disagreed with questionnaire statements suggesting that school science made them 'more critical and sceptical'; made them aware of 'new and exciting jobs'; or 'increased their appreciation of nature'. On a more positive note, there was agreement among boys and girls that school science made them more aware of 'how to take better care' of their health, made them 'more curious about things we cannot explain', would be helpful in everyday life and improve 'career chances', though in the case of the latter boys offered significantly more positive responses than girls. While a 'job in technology' had slightly, though not significantly, greater appeal for boys than girls, neither sex found the prospect of a 'career in science', or 'as much science as possible at school' particularly appealing.

These findings confirm those of other studies of young people's attitudes toward school science in the UK reported in this review, and it is no comfort to know that results obtained from ROSE studies conducted in other countries are not dissimilar. For instance, Sjøberg (2004) reported that few students from schools in industrialised countries had exhibited a strong desire to pursue careers in science or technology, though data showed consistently more positive responses from boys than girls. This contrasts sharply with findings from developing countries, where a career in science or technology was rated highly by boys and girls alike.

The ROSE questionnaire contains three sections in which students are encouraged to indicate, from 108 statements, what they would like to learn about in school science. The statements are intentionally diverse to take account of international differences – for example, '*Phenomena that scientists still cannot explain', 'How radioactivity affects the human body', 'How the sunset colours the sky'* and *'The possibility of life outside Earth'* to *'Ghost and witches: whether they may exist'.* (Sjøberg *et al.,* 2004). In the study by Jenkins and Nelson (2005) this aspect of the questionnaire generated no less than 80 different responses from boys and girls. Gender differences showed a clear preference among boys for 'destructive technologies and events', while girls chose topics related to self, health, mind and wellbeing (p. 49).

The value of such a study is that it goes far beyond the usual survey of attitudes, taking it one stage further in attempting not only to identify those aspects of science found appealing and unappealing, but also encouraging individuals to identify the kind of science that would be appealing. Of course, responses are limited by the nature of topic choices offered to young people, but the selection within the ROSE questionnaires provides ample scope for youngsters to find something appealing. Interestingly, while aspects of organic and ecological farming were rated fairly highly among boys and girls in the Jenkins and Nelson study, no aspects of bioscience featured in their top ten choices of topics they would like to study, though questionnaire choices included *heredity and how genes develop* and *cloning of animals.*

Jenkins and Nelson sound a note of caution concerning the weight attributed to pupils' desires to learn certain topics in science, stressing that it cannot be assumed that an expressed interest to learn can be interpreted as a willingness on the part of individual pupils to "make the intellectual effort and commitment required to achieve the necessary understanding. Nor can it be assumed that, in expressing their preferences, all students are making what might be called informed choices" (p. 53).

One might also posit the argument that absence of enthusiasm shown toward a particular topic, for instance *symmetries and patterns in leaves and flowers*, or *how crude oil is converted into other materials,* rated as the least popular topics among boys and girls respectively in Jenkins and Nelson's study, reflects a lack of understanding about the science underlying such topics and/or the importance of the contribution to a broader understanding of scientific phenomena afforded by study of such topics. If this were found to be the case, it has important implications for the science curriculum and for science teachers, as an integral part of early science education must be to raise awareness of and interest in the foundations of science education, from which an understanding of such topics as *explosive chemicals* and *why we dream when we are sleeping and what dreams may mean* – the two most popular topics for boys and girls respectively in Jenkins and Nelson's study – is established. A greater emphasis on and consideration of the importance of the science curriculum and teaching in science for younger pupils in future research into young people's attitudes towards science is needed as data analysed for the ROSE project (Jenkins and Nelson, 2005) showed that many young people had already decided whether or not they wished to pursue a career in science before they embarked on GCSE courses at the age of 14 to 15 years.

The ROSE project is important for this review as it demonstrates a real effort on the part of the research community to develop quantitative instruments for the measurement of attitudes toward science capable of use with groups of young people – albeit of the same age – in a wide range of industrialised and developing countries, taking account of the need for reliability of data in comparing and contrasting findings. This is the most effective model of large-scale longitudinal research found and is worthy of close attention when considering methodology for the proposed Wellcome Monitor.

Conclusions and recommendations

This review of literature has sought to highlight the many facets of research on young people's attitudes toward science education and attitudes toward the biosciences. The sheer volume of research undertaken in this area over the past four decades is evidence of the level of concern about science education and the numbers of young people turning away from science as a subject of interest and a possible career, a situation all the more worrying given the ever-increasing importance of science in contemporary society.

The body of research reviewed here has confirmed much that was already known both about the problems of conducting valid and reliable research into attitudes toward science and about attitudes among young people towards science. While the majority of studies analysed have identified variables influencing attitudes toward science, on the whole they offer little advice concerning ways in which the problems might be addressed.

In addressing the question concerning the need for a Wellcome Monitor to track changes in attitudes toward science among young people in the UK, the main conclusion to be drawn from this review of literature is that would be a timely development. The proposed rolling programme, utilising complementary research methods of longitudinal biennial surveys and annual qualitative projects, has the potential to provide rich opportunities for in-depth exploration of factors influencing the attitudes of young people toward science. Although the emphasis of the proposed Monitor is on the biosciences, the findings and outcomes of such research are likely to have broader implications for the science curriculum and teaching strategies in the short and longer term.

Recommendations to inform development of the Wellcome Monitor

These recommendations take account of the objectives of the proposed Wellcome Monitor, together with the findings of this review of the literature.

1. In addressing stereotypical images of science and scientists among young people, future research into attitudes toward science and the biosciences in particular needs to include scrutiny of resources and materials, including videos and interactive computer software used to evaluate the extent to which they present realistic images of science and scientists.
2. Research needs to identify the nature of quality teaching in science as perceived by young people. Outcomes would support teachers in the development of practice and provide insight into possible reasons for a decline in perceptions of quality teaching in science as pupils move from primary to secondary schools.
3. Lack of conclusive evidence concerning the strength of influence of parents and peers on attitudes to science leads to the recommendation for focused research in this area, taking account of the need to develop well defined instruments of measure to ensure reliability.
4. An in-depth exploration of cultural and ethnic influences on attitudes toward science is needed to inform initiatives designed, among other

things, to ensure that scientists are representative of the society in which they work.

5. In considering the influence of gender on attitudes, further research should investigate why girls have significantly more positive attitudes toward biology than to the physical sciences as this will help to inform subsequent steps toward improving their attitudes to physics and chemistry.
6. Longitudinal research is needed to determine the extent to which intervention programmes, designed to improve attitudes toward science, are successful in instigating sustained change in attitudes toward science among young people.
7. Lack of conclusive evidence concerning a possible correlation between achievement and attitudes signals the needs for further study. Work is needed to ascertain the extent to which a correlation exists in young people between motivation to learn science and attitudes toward science among young people.
8. The dearth of studies that explore attitudes of young people toward biomedical science suggests there is considerable scope for research in this area. Consideration needs to be given to the extent to which intervention programmes will be required to ensure that the young people involved have a level of scientific knowledge and understanding sufficient to enable them to offer informed views.
9. A longitudinal research study needs to track the steady, and at present apparently irreversible, decline in attitudes toward science among young people over time in an effort to more fully understand more fully why once attitudes begin to decline they continue to do so.
10. Appropriate research methodology to support the aims and objectives of the proposed Wellcome Monitor should take account of a pressing need to understand not only the nature of attitudes toward science and the biosciences among young people but also *why* they hold these attitudes. Such insight would help to inform future developments in science curricula and instructional strategies in the sciences.

Recommended questions for the Wellcome Monitor

The recommendations contained here have been informed by the general aims of the proposed Wellcome Monitor, for instance, the aim of the biennial survey would explore *what* attitudes young people hold toward the biosciences and biomedical science in particular, while qualitative research would aim to explore *why* young people hold certain views and opinions about the biosciences and biomedical science.

Research questions

During the first stage of the biennial survey research design process identification of research questions will be necessary to ensure that whatever methodology is adopted supports the aims of the Monitor. Although specific research questions remain to be determined, the following examples might provide a useful starting point for the areas to be covered:

- How do young people perceive science and scientists?

- What images of bioscience and bioscientists do young people hold?
- Do these images provide a positive role to which young people might aspire?
- How do young people view particular developments in the biosciences?
- What concerns do young people have and not have about ethical issues in the biosciences?
- To what extent are science-related career decisions influenced by attitudes toward science/the biosciences?
- Are there significant gender and other differences in young people's attitudes toward the biosciences?
- What gender differences exist in subject choice/identity as a scientist?
- In what way does the teaching and learning environment influence attitudes towards science/subject choice?
- How do parents influence subject preference and identity as a scientist?
- How does subject preference/attitudes towards bioscience relate to cultural identity?

Biennial survey

Questionnaire design

In answering research questions, decisions about specific questions/statements for inclusion in surveys analysed for this review have typically been made by research teams who have either devised questionnaire items or adapted existing quantitative research instruments to reflect particular areas of interest. It is becoming common practice among researchers to consult a panel of experts from relevant disciplines about questionnaire content in an effort to avoid bias in questions and ensure reliability in data collection.

Survey questionnaires commonly include statements for rating on a Likert scale, which provides a general indication of attitudes toward science. However, scales, by their very nature, feature predetermined questions, and may not be exactly suited to all the specific characteristics of the research question and/or the experiences and understanding of respondents. Other methods of data collection discussed in this review include the presentation of detailed 'dilemmas' (Dawson and Taylor, 2000) to which respondents record their views and decisions about specific situations, revealing knowledge, understanding and attitudes toward controversial scientific issues (Appendix 3, p. 84). One further method is open-response questioning in which respondents express their views and opinions openly on a given subject (ROSE, 2004; see Appendix 3, p. 88). While more open-response questions provide richer data, their disadvantage is the time required for analysis. One main advantage of the proposed Wellcome Monitor research methodology is that a biennial scaled questionnaire might be used to obtain broad views from a large sample, while annual qualitative research might be used to probe in greater depth areas of particular interest.

Questionnaire items/statements

Taking the research questions listed above, the following questionnaire scale and open-response items might be considered for inclusion.

How do young people view science, scientists and science education?
This is an important aspect of the survey in that it provides insight into individual perceptions of science and scientists beyond the classroom, as well as experiences of school science classes.

One useful research tool in eliciting young people's images of science is the Draw-A-Scientist Test (DAST). Although this is typically used with younger pupils to gain insight into early views of science and scientists, if administered to older pupils, such as those in the age group to be targeted by the Wellcome Monitor, it can provide useful information about how young people's attitudes toward science and scientists views have developed by the time they reach the end of Key Stage 3. The procedures are discussed elsewhere in this review (p. 14) and these might be adapted to reflect the age of the sample. Details of indicators for analysis of DAST are provided in detail in Appendix 3 (p. 74) and include the following:

- laboratory coat
- eyeglasses
- facial hair
- symbols of research
- symbols of knowledge
- signs of technology
- captions
- male/female
- signs of labelling
- pens/pencils in pocket
- unkempt appearance

(Mason *et al.,* 1991).

In assessing young people's attitudes toward science and technology in general, Haste (2004) included the following statements to be rated on a four-point Likert scale:

- Science and technology are making our lives healthier, easier and more comfortable.
- I trust scientists to make responsible judgements about the dangers of their work.
- Scientific advances are going too far and fast to be controlled.
- I trust the government to make any necessary laws to control any dangerous developments in science.
- Science is largely irrelevant in my daily life.

(Haste, 2004; p. 6).

Assessment of more general attitudes toward science and science education might be achieved through the use of the types of statements utilised by Stratford and Finkel (1996), including:

- Studying science helps me understand world problems.

- I would like to spend more time doing science in school.
- What I learn about science is important to me in my life.
- Science helps me improve my ability to think and solve problems.
- Science is interesting to me.
- Studying science makes me want to learn more about how the world works.
- Knowing a lot about science will help me when I am an adult.

(Stratford and Finkel, 1996; p. 62).

How do young people view particular developments in the biosciences?

Perhaps the most important initial question here concerns the extent of young people's understanding of the biosciences. Therefore, statements for inclusion might be those that explore individual knowledge and attitudes about specific aspects of bioscience. Although the study conducted by Lewis *et al.* (1997) utilised qualitative research methods, the '*true/false'* response questions they used for a card sort activity provide a helpful starting point in considering the kinds of questions that might be included, for instance:

- When genes are taken out of animals it is painful for them.
- The genetic code in plants works in quite a different way to the genetic code in animals.
- Sheep that produce human insulin have a copy of the human insulin gene in every cell in their body.
- Genes are so small that you need special laboratory techniques for separate different genes.
- Many hundreds of genes can be coded for in just one strand of DNA.

(Appendix 3, p. 84).

Haste's (2004) survey utilised a sliding scale – positive to negative – in eliciting young people's attitudes toward developments in science. Relevant statements for the Wellcome Monitor include:

Positive---------------------------------	***---------------------------------Negative***
I like learning about new developments in technology.	I am not interested in learning about new developments in technology.
I find programmes about medicine medicine and biology interesting.	I am bored by programmes about medicine and biology.

(Appendix 3, p. 85)

A further technique utilised to assess attitudes toward developments in the biosciences is to ask young people what they would like to learn in school science. The items included in the questionnaire would reflect particular areas of interest for the Wellcome Monitor, but might include the following:

- heredity and how genes influence how we develop
- sex and reproduction
- cloning of animals
- how people, animals, plants and the environment depend on each other

- epidemics and diseases causing large losses of life
- biological and chemical weapons and what they do to the body
- how X-rays, ultrasounds, etc. are used in medicine
- how to control epidemics and diseases
- sexually transmitted infections and how to be protected against them
- what we know about HIV/AIDS and how to control it
- how different narcotics might affect the body
- medicinal use of plants
- how gene technology can prevent diseases
- why scientists sometimes disagree
- how scientific ideas sometimes challenge religion, authority and tradition
- inventions and discoveries that have changed the world
- very recent inventions and discoveries in science and technology
- phenomena that scientists still cannot explain.

What concerns do young people have about ethical issues in the biosciences?

The most common approach to this area of enquiry in papers analysed for this review is through the use of animals in research. Stanisstreet *et al.* (1993) assessed young people's attitudes toward the use of animals in everyday life and for science through rated statements using a five-point Likert scale (Appendix 2, p.72). The following statements might be used to inform questionnaire items concerning developments in the biosciences:

- It is acceptable to experiment on animals for medical research.
- It is unacceptable to experiment on animals for medical research.
- It is acceptable to test household products (things like floor cleaners) on animals.
- It is unacceptable to test household products (things like floor cleaners) on animals.

Haste (2004) adopted a somewhat different approach in eliciting young people's attitudes toward ethical issues in science. Respondents were asked to rate the following statements on a four-point Likert scale from *'Agree strongly'* to *'Disagree strongly'*:

- Experimenting on animals is always morally wrong.
- The media have exaggerated the dangers of GM foods.
- I always make sure I buy cruelty-free products.
- The likely effects of global warming have been exaggerated.
- I spend a lot of time thinking about the environment.
- I spend a lot of time thinking about animal welfare.

Developing the theme, Haste focused on attitudes toward ethical dilemmas; the following questions required the response *'Would support'* or *'Would not support':*

- If it were shown that this was necessary to obtain nutritionally improved food that tastes and costs the same as food you eat at the moment, would you support the following:

    - scientific experiments on live animals
    - genetic modification on live animals (e.g. in medical research)
    - genetic modification of plants (e.g. for food stuffs/crops)?

- If it were shown that this was necessary to achieve new agricultural methods that would significantly benefit the environment, would you support the following:

    - scientific experiments on live animals
    - genetic modification on live animals (e.g. in medical research)
    - genetic modification of plants (e.g. for food stuffs/crops)?

(Appendix 3, p. 85.)

To what extent are science-related career decisions influenced by attitudes toward science/the biosciences?

The ROSE project provides perhaps the most focused questions for the elicitation of young people's attitudes toward science-related careers. Using a four-point Likert scale rating system ranging from *'Not important'* to *'Very important'*, statements included the following:

- How important are the following issues for your potential future occupation or job:

    - working with people rather than things
    - working with animals
    - using my talents and abilities; working artistically or creatively in art
    - making, designing or inventing something
    - coming up with new ideas
    - working with something I find important and meaningful
    - earning lots of money
    - developing and improving my knowledge and abilities
    - working as part of team with many people around me?

(ROSE, 2006. For further details see Appendix 3, p. 88.)

Are there significant gender or other differences in young people's attitudes toward the biosciences?

Issues of importance such as gender differences in attitudes toward science might be elicited directly through questionnaire statements, or more subtly at the stage of questionnaire analysis. Assuming that respondents are required to state their gender on the questionnaire, it is a straightforward matter to segregate questionnaires at the first sift stage and compare and contrast responses during the process of data analysis.

Explicit statements might include:

- Studying science is more useful for boys' careers than girls' careers.
- Boys understand things like energy and electricity better than girls.
- Most scientists are men, not women.
- Biology is a girls' subject.

- Physics is a boys’ subject.

(Hadden and Johnstone, 1983b.)

The above questions provide broad insight into possible gender differences in perceptions of and attitudes to science, though statements might be more directly related to possible gender differences in attitude toward the biosciences between boys and girls. However, consideration is needed in ascertaining the extent to which statements/questions suggest assumptions about gender differences.

In conclusion, the proposed Wellcome Monitor provides rich opportunities to stimulate interest in biosciences across the science community and it is hoped that such an endeavour will ultimately go at least some way to encouraging young people to consider science-related careers and to enhancing scientific literacy in the area of biomedical science among the general populace.

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Appendix 1.1: Search strategies

1.1.1 Search strategy for electronic databases

Subject
Young people's attitudes toward science and biomedical science

Population
Students/pupils aged 9 to 19 years

Limits
English language
Published between 1980 and 2006

1.1.2 IngentaConnect

IngentaConnect was searched on 17 May 2006 and 45 broadly relevant records were retrieved.

1. Pupil **and** attitude **and** science
2. Attitude **and** science **and** (biology **or** chemistry **or** physics **or** earth science **or** biomedics **or** biomedical)
3. Student **and** attitude **and** science and (biology **or** chemistry **or** physics **or** earth science **or** biomedics **or** biomedical)
4. Student **and** attitude **and** biomedics **or** biomedical science
5. Student **and** attitude **and** science **and** (biomedical **or** biomedics)
   Limit applied throughout search: 1999 to 2006 – limit dictated by accessible dates on search site

1.1.3 Education Resources Information Center (ERIC)

ERIC was searched on 17 May 2006 and 167 records were retrieved.

1. Pupils **or** students **and** attitudes **or** responses **or** views **and** school **and** science. Limits: keyword; 1980-2006; all publications
2. Pupil **or** student **and** attitudes **or** responses **or** views **and** school **and** science. Limits: title; 1980-2006; publications: journal articles; doctoral theses; books; research reports
3. 'Biomedical science' Limit: 1980-2006; all publications (none relevant to study)
4. Pupil **and** attitude **and** biomedical **and** science. Limit: 1980–2006
5. Pupils **and** attitudes **and** biomedical **and** research. Limit: 1980–2006
6. Student **and** attitude **and** biomedical **and** science. Limit: 1980–2006
7. 'Attitudes' **and '**biomedical science'. Limit 1980–2006
8. 'Attitudes' **and '**biomedical research'. Limit 1980–2006

ERIC was again searched on 8 June, 12 June and 16 June and 1299 records were retrieved.

1. Pupil **or** student **and** views **or** interest **and** science **or** bioscience
2. Pupil **or** student **and** views **or** attitude **and** genetics **or** biomedical **and** science

3. Pupil **or** student **and** views **or** interest **and** science **and** education
4. Student **or** young **and** people **and** attitude **or** interest **and** science
5. Student **or** young **and** people **and** attitude **or** response **and** science
6. Student **or** young **and** people **and** attitude **or** interest **and** biological **and** science
7. Student **or** young **and** people **and** attitude **or** response **and** biology
8. Student **or** young **and** people **and** views **or** interest **and** biotechnology
9. Secondary **and** school **and** pupil **or** student **and** attitude **or** interest **and** bioscience **or** science **or** genetics
10. Primary **and** school **and** pupil **and** attitude **or** interest **and** science
11. Student **or** young **and** people **and** conception **and** biomedics **or** bioscience **or** genetics
12. Student **or** young **and** people **and** opinion **and** biomedics **or** bioscience **or** genetics
13. Measures **and** student **or** young **and** people **and** attitude **or** conception **and** biology **or** biological **and** science
14. Gender **and** difference **and** science **and** education
15. Gender **and** difference **and** bioscience
16. Gender **and** difference **and** biomedical **and** science
17. Gender **and** difference **and** science **or** genetics
18. Girls **and** attitude **or** opinion **and** science **or** bioscience
19. Boys **and** attitude **or** opinion **and** science **or** bioscience
20. Gender **and** differences **and** science **and** education
21. Gender **and** differences **and** genetics
22. Gender **and** differences **and** biomedical **and** science
23. Gender **and** differences **and** bioscience

Limits applied throughout: English language; 1980–2006.

1.1.4 CSA ILLUMINA: including ERIC and MEDLINE databases

CSA Illumina was searched on 18 May 2006, using the Institute of Education Journal Index interface and 174 records were retrieved.

1. Pupil* **or** student* **and** attitude* **or** view* **and** school **and** science
   Limits: 1980–2006; publications in English
2. Pupil* **and** attitude* **and** school **and** science
   Limits: 1980–2006; publications in English; ERIC database only
3. Student* **and** attitude* **and** biomedical science **or** biomedics
   Limits: 1980–2006; publications in English. With multiple databases: **ERIC and Medline**
4. Attitude* **and** biomedical science **or** biomedics
   Limits: 1980–2006; publications in English. With multiple databases: **ERIC and Medline**
5. Pupil* **and** attitude* **and** biomedical science **or** biomedics
   Limits: 1980–2006; publications in English. With multiple databases: **ERIC and Medline**
6. Young **and** people **and** biomedical science **or** bioscience
   ERIC and Medline
   No limits set for search

1.1.5 Education-line

Education-line database was searched on 24 May 2006 and 24 records were retrieved.

1. Pupil attitude school science

Link on database of publications to:

▼

Pupil Attitude

▼

Handsearch of 118 listed publications

▼

Results: 21 broadly relevant records

2. Biomedical science

Link on database of publications to:

▼

Biomedical

▼

Handsearch of listed publications

▼

Results: 3 publications listed none relevant to study

1.1.6 Dialog Datastar: including BEI; AEI; ERIC

The Datastar database was searched on 24 May 2006 and 58 records were retrieved. Databases searched: ERIC and BEI only

1. Attitudes **and** biomedical science **or** biomedics
   Limits: 1980 -2006; English Language
2. Pupils **or** students **and** attitudes **and** biological science
   Limits: 1980 -2006; English Language
3. Attitudes **and** school **and** science
   Limits: 1980 -2006; English Language
4. Pupils **or** students **and** attitudes **and** school **and** science
   Limits: 1980 -2006; English Language
5. Young **and** peoples **and** attitudes **and** biomedical **and** science
   No limits set
6. Young **and** peoples **and** attitudes **and** school **and** science
   No limits set
7. Young **and** people **and** attitude **and** bioscience
   No limits set
8. Young **and** people **and** science
   Limits: 1980–2006; English Language
9. Young **and** people **and** bioscience
   No limits set
10. Young **and** people **and** school **and** science **or** bioscience
    Limits: 1980–2006; English Language

1.1.7 ISI Web of Knowledge

The Web of Knowledge database was searched on 18 May 2006 and 266 records were retrieved

1. Attitudes **and** biomedical **and** science

No limits applied
2. Attitudes **and** biomedics
   No limits applied
3. Attitudes **and** bioscience
   No limits applied
4. Biomedical **and** science
   No limits applied
5. Biomedical **and** science
6. School **and** biomedical **and** science
   No limits applied
7. Pupils **and** bioscience
   No limits applied
8. Young **and** people **and** bioscience
   No limits applied

1.1.8 Psci-Com

The Psci-Com site was searched on 18 May and 2 records were retrieved. No limits were applied to searches.

1. Attitudes **and** biomedical **and** science
2. Pupils **and** attitudes **and** biomedical **and** science
3. Students **and** attitudes **and** biomedical **and** science
4. Young **and** people **and** attitudes **and** biomedical **and** science
5. Young **and** people **and** view **and** bioscience
6. Students **and** attitudes **and** bioscience
7. Young **and** people **and** attitudes **and** bioscience

1.1.9 Eurobarometer

Eurobarometer was searched on 5 June 2006 and 99 records were retrieved though none were relevant to this review.

Eurobarometer Survey Series (handsearched):
1. Biomedical science
2. Attitudes biomedical science
3. Link to European Commission – Research – Publications
4. Life sciences
5. Science and society
6. Young people attitude genetics
7. Pupils and genetics

Limit applied: education; 1980–2006

Link to ESDS International
1. Working papers searched (majority German language records), no search string facility available

Link to ISYSweb with search facility
2. Student* **and** attitude* **and** genetics
3. Young **and** people **and** attitude* **and** bioscience
4. Young **and** people **and** attitude* **and** biomedical **and** science
5. Student* **and** attitude* **and** bioscience
6. Student* **and** interest **and** biomedical **and** science

7. Student* **and** views **and** genetics
8. Student***and** interest **and** bioscience
9. Student* **and** attitude* **and** science

Limit applied: English text; published between 1980 and 2006.

1.1.10 National Science Foundation

National Science Foundation was handsearched on 5 June 2006 and no relevant records were retrieved.

1. Overview of NSF research – links to:
    - Education
    - Biology
    - Biomedical science
    - Bioscience

No limit applied.

1.1.11 United Kingdom Data Archive (UKDA)

UKDA was handsearched 6 June 200 and 31 records were retrieved; none were relevant to this review.

1. Pupil attitudes science
2. Pupil attitudes biomedical science
3. Pupil attitudes bioscience
4. Pupil attitudes genetics
5. Student attitudes science
6. Student attitudes biomedics
7. Student attitudes biomedical science
8. Student attitudes bioscience
9. Student attitudes genetics
10. Student views science
11. Student views biomedical science
12. Student views bioscience
13. Student views genetics
14. Biomedical science
15. Biomedics
16. Bioscience

Limits applied: English language; 1980–2006.

1.1.12 Inter-University Consortium for Political and Social Research (ICPSR)

ICPSR was searched on 6 June 2006 and 220 records were retrieved; none were relevant to this review.

1. Science education
2. Student attitude science
3. Student attitude biomedical science
4. Student attitude bioscience
5. Student attitude genetics
6. Attitude science education
7. Views science

8. Views biomedical science
9. Views bioscience
10. Biomedical science
11. Bioscience

Limits applied: English language; 1980–2006.

1.1.13 Networked Social Science Tools and Resources (NESSTAR)

NESSTAR was handsearched on 8 June 2006 and no relevant records were retrieved.

1.1.14 Council for European Social Sciences Data Archives (CESSDA)

CESSDA was handsearched on 8 June 2006 and no relevant records were retrieved.

1. Links to UKDA (previously searched)
2. Links to other UK and USA sites – none relevant to this review

Appendix 1.2 Journals handsearched

The following journals were handsearched for potentially relevant papers for the period 1980–1995; the period of time prior to inclusion on electronic databases:

Educational Research

European Journal of Science Education

International Journal of Science Education

Journal of Educational Research

Journal of Research and Development in Education

Journal of Research in Science Teaching

Journal of Science Education and Technology

School Science and Mathematics

Studies in Science Education

Research in Science and Technological Education

Other key journals were handsearched for the entire period from 1980–2006 as electronic databases were unavailable:

Education Studies

Journal of Biological Education

Journal of Environmental Education

Public Understanding of Science

School Science Review

Science Education

Studies in Educational Evaluation

Appendix 1.3

Criteria for inclusion of papers in Phase 1 searches

1. Focus on young people's (pupils or students) attitudes (or views, interest or responses) to school science and the biosciences.
2. Utilise quantitative research methodology.
3. Utilise qualitative research methodology (to be included in the review where this serves to illuminate shortcomings in existing quantitative studies and indicates what is not yet known quantitatively).
4. Have been published after 1980.
5. Describe the methods of data collection and analysis, and the target population.
6. Attempt to establish the reliability and validity of data analysis.
7. Report on the aims and objectives of the research.
8. Show how they have used what is already known, for example through the provision of a literature review.

Appendix 1.4

Recruitment of experts

On 7 June 2006 Professor Michael Reiss sent the following email to 12 experts from the UK, Europe, Canada and the USA:

Dear

Sue Collins, Disi Lian, Shirley Simon and I are undertaking a literature review of research conducted on young peoples attitudes to science education and biomedical science, funded by the Wellcome Trust. This is a small-scale study that only began on May 15th and needs to be finished by early August. I attach our first progress report. I am taking the liberty of e-mailing you to say that if you are aware of any references that we should consult that are not in the attached, we would be very grateful to hear of them. We are finding it very difficult to find much on young peoples (5–19 year-olds) attitudes to biomedical science.

Thanks!

Michael

A total of 11 replies were received; the majority offered valuable recommendations and these were added to the records for screening as part of Phase 1 of the review process.

Appendix 1.5a

Inclusion and exclusion criteria for determining suitability of records

Criteria for inclusion of studies in review

1. Focus on attitudes (views, responses, interests)
2. Measure attitudes to science education (integrated and general science; biology; chemistry; physics; Earth sciences), including biomedical science (biosciences)

3a. Utilise quantitative research methodology
3b. Utilise a survey approach
3c. Utilise qualitative research methodology where this serves to illuminate shortcomings in quantitative studies

4. Focus on young people in the 9–19 age range
5. Describe the methods of data collection and analysis, and the target population
6. Attempt to establish the reliability and validity of data analysis
7. Report the aims and objectives of the research
8. Show how they have used what is already known, e.g. literature review
9. Have been published between 1980 and 2006
10. Have been published in English.

Exclusion of studies

A. Exclusion on scope

1. Do not report attitudes (views, responses, interests) of young people (pupils/students)
2. Do not measure attitudes to science (integrated and general science; biology; chemistry; physics; Earth sciences), including biomedical science (biosciences)
3. Do not utilise quantitative research methodology, unless qualitative research methodology used to illuminate shortcomings in quantitative studies
4. Do not adopt a survey approach
5. Do not focus on young people in the 9–19 age range.

B. Exclusion on study type

1. Editorials, commentaries or book reviews
2. Policy documents, syllabuses or specifications
3. Resources
4. Bibliographies
5. Methodology papers
6. Theoretical (non- empirical papers).

C. Exclusion on setting in which study is carried out

1. Not published in English
2. Published outside the period 1980–2006.

Appendix 1.5b

Examples of abstract screening using codes outlined in Appendix 1.4a

Codes	Reference
A: 1,2,3,4,6,7,8,11,12	Breakwell GM & Bearsell S. (1992) Gender, parental and peer influences upon science attitudes and activities. *Public Understanding of Science,* Vol. 1, No. 2, 183-198.
Notes: UK. Focus on gender, parental and peer influence on attitudes to science of 11–14 year olds in UK. Survey of 391 pupils	

A1, A2, A3, A4, A6, A7, A8, A9, A10, A11, A12	Caleon I & Subramaniam R. (2005) The impact of a cryogenics-based enrichment programme on attitude towards science and the learning of science concepts. *International Journal of Science Education* Vol. 27, No. 6, 679-704.
Notes: Full paper analysed. No data about attitudes to biomedical science.	

A: 1, 6 Insufficient info for coding	Dawson C. (2000) Upper primary boys' and girls' interests in science: have they changed since 1980? *International Journal of Science Education,* Vol. 22, No. 6, 557-570.
Notes: Australia. Explores gender differences in attitudes to science. Study undertaken in 1980 and repeated in 1997 with Y7 pupils. Full document screening needed – insufficient detail in abstract.	

A: 2, 3,6, 7, 8 8,11, 12 B: 1?	Den Brok P, Fisher D & Scott R. (2005) The importance of teacher interpersonal behaviour for student attitudes in Brunei primary classes. *International Journal of Science Education* Vol. 27, No. 7, 765-779.
Notes: Brunei. Possible: Looks at science subject related attitude in primary classroom and the relationship with perceptions of teachers' interpersonal behaviour. Is it attitudes to science or to teachers? Full document screening needed.	

A: Not a survey B:	Gardner P L. (1995) Measuring attitudes to science: undimensionality and internal consistence revisited. *Research in Science Education,* Vol. 25, No. 3, 283-289.
Notes: Not a survey of attitudes. In-depth analysis of summated attitude scales. Useful for background? ***Theoretical background.***	

Appendix 1.6

Example summary of a full document that meets criteria for inclusion

Choi K and Cho H-H. (2002) Effects of teaching ethical issues on Korean school students' attitudes towards science. *Journal of Biological Education,* Vol. 37, No. 1, 26-31.

Focus of the study

To examine the effect of formal teaching of ethical issues on science on Korean middle school students' attitudes to science. Included an intervention programme. Also examined whether teaching of ethical issues impacted on students achievement levels in science by means of pre and post-test evaluation.

Commissioning organisation

Not specified

Type of study:

Quantitative
Survey
Longitudinal research
Qualitative research (meeting criteria for inclusion)

Sample size

132 grade 8 students (13–14 years) from four classes in Korean middle schools. Two classes formed the control group and two classes the experimental group. Equal numbers of male and female students in classes.

Base questions

Questionnaire consisted of 18 Likert-type scale items in five domains:

- Students' interest level in science
- Students' perceptions of the practicality of science knowledge'
- Students' opinions on how science is defined
- Students' perception on relationships among science, scientists and society
- Students' perceptions of the value of science.

Subsidiary questions

Intervention for experimental group comprised took 25 class hours for seven weeks and 20-minute pre- and post-tests were administered. Teaching and learning materials developed by research team to address ethical issues in science – control group used usual textbook material. Intervention included guided discussion and sheets for students to express own ideas for each question. Also read articles or papers and asked to orally present solutions to problems outlined in papers. A post-test was administered to assess extent to which teaching ethical issues impacted on students' attitudes to science. Students' achievements were also re-evaluated after the intervention.

Scales used to classify responses (Likert, Rasch, Thurstone, Other please state)

Likert-type scale used to classify responses to questionnaires devised by research team (Attitude Assessment in Science Questionnaire – AASQ) but based on Views on Science-Technology-Society (VOSTS) evaluation tool (Aikenhead *et al.*, 1989).

Form of analysis used (univariate, multivariate, factor, cluster, principal components)

Post-tests following intervention were analysed using ANCOVA in which post-test scores were treated as covariate. Results indicated no significant results, but mean was higher in experimental group. ANCOVA also used to measure differences between group (control and experimental) responses to questionnaires.

Summary of key findings

Pre and post-testing showed no significant gains. Students' interest level in science in experimental group where ethical issues discussed. Students in experimental group perceived more relevance for science and practicality of science knowledge and content to everyday life. No significant difference between groups in their definition of science. Students in experimental group perceived a higher level of social responsibility for scientists than the control group. Students in experimental group identified need to explore and solve ethical issues alongside developments in science. No significant difference emerged in students' perceptions of the value of science.

Any additional comments

Results showed benefits in teaching ethical issues directly on students level of interest in science and their attitudes to ethical issues covered in intervention (see paper p. 28 for list); question remains whether it was the materials or the strategies used for teaching that influenced responses – i.e. students given opportunities to express their own views and ideas and to discuss topics of interest to them.

Appendix 2

Explanation of commonly used research scales

There are a number of standardised rating scales used to assess young people's attitudes toward science.

Scales are validated measuring instruments whose psychometric properties have been established. The advantage of scales is that they are easy to use and relatively easy to administer and complete. One disadvantage in using scales is that they deal with predetermined questions and problems consequently they may not be exactly suited to all the specific characteristics of the research question and/or the experiences/understanding of respondents. Scales tend to offer a broad-brush approach to data collection rather than an in-depth exploration of individual attitudes and experiences.

There are three commonly used types of standardised scales:

- summated rating, or Likert scale
- semantic differential
- Thurstone scale (also called Equal-appearing interval scale).

Summated rating or Likert scale
Respondents are presented with a series of statements in a single instrument, or questionnaire. Respondents are asked to indicate whether they *'Strongly Agree', 'Agree', 'Disagree'* or *'Strongly Disagree'*.

Semantic differential
Respondents choose between two polar opposite adjectives, for example:

- Interesting v. Boring
- Simple v. Complex
- Uncaring v. Caring
- Useful v. Useless.

Thurstone (Equal-appearing interval scale)
The Thurstone scale is designed to generate groups of indicators of a variable having an empirical structure among them.

Interest inventories

Interest inventories are questionnaires that ask respondents about their likes and dislikes, usually associated with particular science topics. Typically, respondents are asked to rate on a three or five-point Likert scale the extent of their enjoyment of particular science topics. Responses are used to develop a personal interest profile, which is then compared to the profiles of other students or to groups of students. A high level of similarity between individual profiles and the profiles of other students provides insight into the topics of general interest and those found less appealing among students. Although the results of interest inventories might be used to support suggestions for revisions to the school science curriculum, they do not provide information concerning individual views about the nature of desired change to the science curriculum.

Preference ranking

This is similar to interest inventories in that respondents are asked to identify science topics of particular interest. Preference ranking encourages respondents to rank science topics in order of preference, usually with the most favoured first.

Appendix 3

Examples of questionnaire items for each section of the review

A large number of papers analysed for this review did not provide details of questions or statements included in questionnaires, focus groups or individual interviews. Data analysis tended to list the main categories of the research rather than details of specific questions asked. The following examples are extracted from papers where at least some indication of questionnaire content was provided.

Images of science and scientists

The Draw-A-Scientist Test (DAST), widely used to assess young people's images of science and scientists, features a set of indicators for the standard image of a scientist against which individual attitudes toward science are analysed. Typical indicators include:

1. Laboratory coat
2. Eyeglasses
3. Facial hair
4. Symbols of research such as:
    a. Test tubes
    b. Flasks
    c. Microscope
    d. Bunsen burner
    e. Experimental animals
    f. Other
5. Symbols of knowledge:
    a. Books
    b. Filing cabinets
    c. Other
6. Signs of technology (products of science):
    a. Solutions in glassware
    b. Machines
    c. Other
7. Captions
8. Male
9. Signs/labelling
10. Pencils/pens in pocket
11. Unkempt appearance

(Mason *et al.* 1991; p.195).

Classroom environment

Paper analysed for this aspect of the review tended to base questionnaire content on the *Learning Environment Inventory* (LEI). The initial development and validation of the LEI began in the late 1960s in conjunction with the evaluation and research related to the Harvard Physics Project. The final version of the LEI contained a total of 105 statements, within 15 separate categories, descriptive of typical school classes. Respondents are encouraged to express their degree of agreement or disagreement with each statement using a four-point Likert scale of: *Strongly Disagree, Disagree, Agree, Strongly Agree.* The LEI categories are as follows:

- Cohesiveness: ‘All students know each other very well’
- Diversity: ‘What students do in class is very different on different days’
- Formality: ‘Students are asked to follow strict rules’
- Speed: ‘The pace of the class is rushed’
- Material Environment: ‘Students would be proud to show this classroom to a visitor’
- Friction: There is a group of students that interfere with class activities’
- Goal Direction: ‘Most students know the goals of the course’
- Favouritism: ‘Certain students are favoured more than the rest’
- Difficulty: ‘Most students find this subject matter easy’
- Cliqueness: ‘Certain students stick together in small groups’
- Satisfaction: ‘Students are well satisfied with the work of the class’
- Disorganisation: ‘The class is well organised’
- Competitiveness: ‘Students do not compete with each other here’

(Adapted to include examples from Fraser, 1982; Haladyna *et al.,* 1992; Henderson *et al.,* 1998).

Teacher influence

Ebenezer and Zoller (1993) adapted the *Science Assessment Instrument,* devised by Bateson *et al.* (1986), to include a questionnaire with two components; *Classroom Practices and Activities* and *School Science.* ***Classroom Practice and Activities:*** Grade ten students were asked to respond to the following statements in terms of ‘*Always’, ‘Often’, ‘Sometimes’* or ‘*Never’*:

1. We watched the teacher do experiments in science.
2. The teacher handed out notes in science.
3. We copied the teacher’s notes from the blackboard or overhead projector to our own notebooks in science.
4. We worked in small groups (two to five students) to do experiments in science.
5. We did experiments in science individually (without any lab partners).
6. We used a computer to help us in science classes.
7. The teacher used our ideas and suggestions when planning science lessons.
8. We used library books when we were in science class.
9. We did homework in science.

School science: The statements in this section sought to gain insight into students’ enjoyment of school science. Students were asked to respond to the following statements in terms of ‘*Strongly Disagree’, ‘Disagree’, ‘Agree’* and *‘Strongly Agree’*:

1. I like to study science in school.
2. I feel the study of science in school is important.
3. Science is dull.

4. I do not enjoy science.
5. I would like to study more science.
6. Science classes are boring.
7. Science is a valuable subject.

(Ebenezer and Zoller, 1993; p.178).

Teacher personality attributes

Pupils were asked to respond to the following teacher characteristics in terms of *'Never', 'Occasionally', Frequently'* and *'Always'*:

Creative	Emotional
Good Communicator	Committed
Patient	Friendly
Honest	Demanding
Competent	Inspirational
Warm	Curious
Caring	Exciting
Confident	Adventurous
Attractive	Good Rapport
Informal	Enthusiastic
Good Role Model	Effective Disciplinarian
Supportive	Professional
Funny	Charismatic
Knowledgeable	Fair
Polite	Fun

Instructional methods

The second section of the questionnaire asked students to respond to the following preferred instructional methods using the same terms as listed above:

Memorisation	Lab Activities
Textbooks	Peer Groups
Lectures	Research Papers
Films A/V	Teacher Demonstrations
Computers	Worksheets
Other Question/Answer Written Work	Discussion

Guest Speakers	Projects
Field Trips	Quizzes / Tests

(Eichinger, 1997; p.125).

Parental influence

George (2000) utilised data from the *Longitudinal Study of American Youth* to inform her study of change in students' attitudes toward science, monitoring the following variables of parental influence on their children's attitudes toward school science:

My parents:

1. Tell me how proud they are when I make good grades.
2. Insist I do my homework.
3. Ask me a lot of questions about what I do in school.
4. Tell me how confident they are in my ability.
5. Reward me for getting good grades.
6. Often help me to understand my homework.

Peer influence

Atwater *et al.* (1995) explored the influence of peers on young people's attitudes toward science as part of a larger study about the range of factors influencing individual attitudes. Students were asked to rate the following statements on a five-point scale from *'Strongly agree'* to *'Strongly disagree',* under the subset of '*Significant others'*:

1. *Friends' attitudes toward science:* My best friend likes science.
2. *Attitude toward other students:* The students work well in this class.
3. *Attitude toward science teacher:* Sometimes my science teacher makes me feel dumb.
4. *Attitude toward family:* I argue a lot with my family.
5. *Family attitude toward science:* My brothers and sisters like science.

(Atwater *et al.,* 1995; p. 668).

Adopting a similar approach to questions, George's (2006) cross-domain analysis of young people's attitudes toward science, asked students to rate the following statements on a four-point scale ranging from *'Strongly agree'* to *'Strongly disagree'*:

My friends:

1. Like science.
2. Do well in science.
3. Hope to become scientists, doctors, engineers, or mathematicians.
4. Know how to write computer programs.

(George, 2000; p. 577).

Influence of culture and ethnicity

The papers analysed for this review did not include questionnaire items/statements specifically designed to assess the extent of the influence of culture and ethnicity on young people's attitudes toward science. Where such influences were highlighted in discussion (for example, Atwater, 1986; Atwater *et al.,* 1995), these were based on responses to more general statements concerning attitudes toward science by a particular sub-set of the sample recruited for the study.

Influence of gender

The influence of gender on attitudes toward science has been explored in two ways. Firstly, direct questions are asked about the relevance of science for boys and girls. An example of this approach is the final phase of a longitudinal study conducted by Hadden and Johnstone (1983b) that explored gender differences in attitudes toward science among 14 year olds. Students were asked to rate the following statements using a five-point Likert scale ranging from *'Strongly agree'* to *'Strongly disagree'*:

1. Studying science is more useful for boys' careers than for girls' careers.
2. Boys understand things like energy and electricity better than girls do.
3. Physics is a boys' subject.
4. Most scientists are men, not women.
5. Biology is a girls' subject.

(Hadden and Johnstone, 1983b; p. 435).

Secondly, questions have been designed to assess individual attitudes toward science with gender differences analysed in completed questionnaires. An example of this approach is the study of attitudes towards science among American male and female biology students conducted by Kahle *et al.* (1985). The research team incorporated a number of questions included in the 1976 National Assessment of Educational Progress to facilitate comparison of data concerning gender differences in attitudes toward science. Students were asked to rate the following statements on a four-point Likert scale including *'Often', 'Sometimes', 'Seldom'* and *'Never':*

1. **Science activities**

A) Have you ever worked with or experimented with /used/seen/visited:

- Electricity?
- Erosion?
- Telescope?
- Electricity meter?
- Animal skeleton?
- Solar heat collector?
- North star?
- Moon through a telescope?
- Skyscraper?
- Electricity plant?
- Rock quarry/mine?

B) Have you ever:

- Wired together an electric circuit?
- Touched a snake/lizard?
- Taken something apart to see how it works?
- Made a magnet with electricity and wire?

- Fixed something electrical?
- Fixed something mechanical?
- Taken care of an unhealthy animal?

2. Extra-curricular activities

How often have you done one of these when not required for science classes:

- Read science articles in magazines?
- Read science articles in newspapers?
- Watched science TV shows?
- Read books about science/scientists?
- Talked about science with friends?
- Done science projects?
- Worked with science-related hobbies?

3. **Science classes**

A) How often have science classes made you feel:

- Curious?
- Stupid?
- Confident?
- Successful?

B) How often do you like to go to science classes?
C) How often are you afraid to ask questions in science class?
D) [To be rated '*Definitely Yes'* or *'Definitely No'*] Would you like to work at some job that lets you use what you know about science?
E) [To be rated '*Definitely Yes'* or *'Definitely No'*] Do you want to work with scientists in an effort to solve problems?
F) [To be rated '*Definitely Yes'* or *'Definitely No'*] Would you like to know more about jobs in a science/engineering field?
(Kahle *et al.*, 1985; p. 391-392).

In another example, Parkinson *et al.* (1998) in their UK study of Key Stage 3 students' attitudes toward science, related their questionnaire items/statements more directly to school science. Students were asked to rate statements on a five-point Likert scale including *'Strongly agree', Agree', 'Not sure', 'Disagree'* and *'Strongly disagree'*. The following statements are in order of significant differences found between boys' and girls' attitudes toward science in order of decreasing overall means:

1. I like doing experiments in science lessons.
2. I like learning how things work.
3. I think science is interesting.
4. I think science is very important.
5. Science helps to solve problems.
6. I think that learning science will help me get a job.
7. I never understand what we should be doing during practical investigations.
8. I think science is enjoyable.
9. I think the science we do is too hard.
10. I like learning about the stars and the planets.
11. The science we do in school is unimportant outside school.
12. Science is used a lot outside school.

13. Science lessons are too long.
14. I do well in science.
15. I find it difficult to work on my own in science.
16. I think we have too many science tests.
17. I look forward to my science lessons.
18. I find that planning and doing investigations in science is frustrating.
19. Copying from worksheets in science is a waste of time.
20. I think there are too many facts to learn in science .
21. Writing about science is boring.
22. I think reading science textbooks is boring.
23. More time should be spent on science at school.
24. I think we should have more science lessons at school.
25. I should like to belong to a science club.
26. Science is my favourite subject.

(Parkinson *et al.,*1998; p. 169).

Intervention programmes

Gibson and Chase (2002) utilised The Science Opinion Survey (TSOS) in exploring attitudes of young people toward science pre and post intervention. Students were asked to rate statements on a five-point Likert scale including '*Strongly agree', 'Agree', 'Not sure', 'Disagree', 'Strongly disagree'*. Examples of questionnaire statements include:

1. Science lessons are fun.
2. I really enjoy going to science lessons.
3. I would like to be a scientist when I leave school.
4. Working in a science laboratory would be an interesting way to earn a living.
5. I look forward to science lessons.
6. Science is one of the most interesting school subjects.

(Gibson and Chase, 2002; p. 697).

A study conducted by Boone and Edson (1994) provides a useful example of a straightforward approach to intervention questionnaires where the same questions were given to students pre and post intervention. Students rated the following statements on a four-point Likert scale from *'Strongly agree'* to *'Strongly disagree'*, before and after the introduction of technology into a science topic:

1. I would enjoy using a computer to measure the temperature of an object.
2. Computers can help me learn reading.
3. I would learn more physical science if I could make graphs on a computer screen.
4. I would enjoy collecting science data and then sending it by computer to other physical science students elsewhere in the world.
5. I would enjoy using a computer to measure the amount of magnetism an object has.
6. I would enjoy using a computer to measure the amount of light from a light bulb.

7. I would learn more physical science if I could print out graphs on a computer screen.
8. I would enjoy printing our graphs created with the aid of a computer.
9. If a computer were available for use in my science class, I would enjoy using it.

(Boone and Edson, 1994; p. 242).

A study conducted by Stratford and Finkel (1996) explored attitudes toward science among students enrolled in biology courses and those following integrated science courses. The questionnaire was divided into three parts, *Attitudes toward science classes, Attitudes toward science* and *Motivation for studying science*.

Attitudes toward science classes

Students were asked to rate the following statements in the range '*Almost Always', 'Often', 'Sometimes', 'Seldom'* and '*Almost Never'*:

1. In science classes, I debate scientific ideas with other students.
2. In science classes, the information I collect is used by others.
3. In science classes, I learn a lot from other students.
4. In science classes, I collect information.
5. In science classes, I figure out what information I collected means.
6. In science classes, I draw conclusions from information I collected.
7. In science classes, I have a chance to get involved in what is being taught.
8. In science classes, I have to answer questions that make me think about science problems.
9. In science classes, textbooks are the main source of science information.
10. In science classes, what I learn one day I use in later science lessons.
11. In science classes, I investigate questions about how things work.
12. In science classes, I use other skills like math, social studies or language arts.
13. For science tests I have to memorize many definitions of science words.
14. For science tests I have to reason and think out ways to solve problems.

Attitudes toward science

Students were asked to rate the following statements using a five-point scale ranging from *'Strongly Agree'* to *'Strongly Disagree'*:

1. Studying science helps me understand world problems.
2. I would like to spend more time doing science in school.
3. What I learn about science is important to me in my life.
4. Science helps me improve my ability to think and solve problems.
5. Science is interesting to me.
6. Studying science makes me want to learn more about how the world works.
7. Knowing a lot about science will help me when I am an adult.

Motivation for studying science
Students were asked to rate the following statements on a five-point scale including *'Always true of me', Often true of me', Sometimes true of me', Rarely true of me'* and *'Never true of me'*:

1. Even if the work in science is hard, I can learn it.
2. No matter how hard I try, there is some science class work I'll never understand.
3. Some of the work we do in science is too difficult for me.
4. If I have enough time, I can do even the hardest problems in science.
5. When the work in science class is difficult, I either give up or do the easy parts.
6. When I don't understand my science work, I get the answers from my friends.
7. During science activities, I sometime just copy what other students write down.
8. When doing my science schoolwork I guess a lot so that I can finish quickly.
9. I try to figure out how things I learn in science are connected to thing in the real world.
10. In science I try to connect new work to what I learned before.
11. When I make a mistake in science class, I try to figure out why.
12. In science class I spend some time thinking about how to do my work before I start it.
13. When I am studying science, I try to understand the main ideas, not just memorize the facts.
14. I like work in science that is easy.
15. The main reason I do my work in science is because we get grades.
16. I would feel really good if I were the only one who could answer the teacher's question about science.
17. I don't care whether I understand something or not in science, as long as I get the right answer.
18. I feel successful in science class if I do better than other students.
19. I'd like to show my teacher that I'm smarter than other students in science.
20. The main reason I work hard in science is to learn new things.
21. It is important to me that I really understand the work in science class.
22. Understanding the work in science is more important to me than the grade I get.
23. The main reason I do my work in science is because it makes me feel good inside.
24. I like science the best when it is really challenging.
25. I like science work that I'll learn from, even if I make a lot of mistakes.

(Stratford and Finkel, 1996; p. 62).

Relationship between attitude and achievement
The papers analysed for this review did not include questionnaire items/statements specifically designed to assess the relationship between attitude toward science and achievement in science. Studies tended to explore individual student attitudes, elicited through responses to general attitude

questions, against grades attained in science tests administered as part of the study (for example, Engstöm and Noonan, 1990), or against tests and examinations in the normal course of school science education (for example Oliver and Simpson, 1988; Weinburgh, 1995). A number of studies attempted to measure *Aspiration in science* as an indicator of motivation and achievement (for example, Papanastasiou and Papanastasiou 2004; House, 1993;). In the following example students were asked to rate on a five-point Likert scale from *'Strongly Agree'* to *'Strongly Disagree'* the statements:

1. My mother thinks it is important for me to be placed with the high-achieving students.
2. Most of my friends think it is important for me to be with the high-achieving students.
3. I think it is important to be placed with the high-achieving students.

(Papanastasiou and Papanastasiou, 2004; p. 7).

Changing attitudes over time: cross-sectional and longitudinal studies

Longitudinal studies relevant to this review tended to utilise the same questionnaires at different intervals to ascertain changes in young people's attitudes toward science. Simpson and Troost (1982) provided a useful example of a questionnaire with several subdimensions, designed to explore a range of factors influencing attitudes toward science among students of different ages. Dimensions and examples of statements included:

1. Science affect: *I like science*.
2. Science self-concept: *I consider myself a good science student.*
3. General self-esteem: *I like myself.*
4. Locus of control: *Luck seems to be more important in life than hard work.*
5. Achievement motivation: *I try hard to do well in science.*
6. Science anxiety: *My mind goes blank when I do science.*
7. Science class – emotional climate: *I feel nervous in science class.*
8. Science class – physical environment: *Our science classroom contains a lot of interesting equipment.*
9. Science class – other students: *The students in this class aren't much fun.*
10. Science teacher: *My science teacher encourages me to learn more science.*
11. Science curriculum: *We learn about important things in science class.*
12. Family – general: *I am a member of a happy family.*
13. Family – science: *My parents encourage me to learn science.*
14. Friends and best friend: *My friends like science.*
15. School: *I feel like I'm in prison when I'm in school.*

(Simpson and Troost, 1982; p. 772-773).

The study undertaken by Hadden and Johnstone (1983; 1983a; 1983b) also utilised repeat questionnaires over a period of time to explore changes in young people's attitudes toward science. One example utilised science curriculum content on which to based questions. Students completing the first year of the Scottish Integrated Science Course were asked to rate the following science topics on a five-point Likert scale ranging from '*Very interesting'* to *'Very boring'*:

1. Mixing chemicals.
2. Weighing chemicals.
3. Studying worms and other animals.
4. Doing 'keys'.
5. Experiments about energy changes.
6. Using energy converters, e.g. the dynamo.
7. Studying solids, liquids and gases.
8. Joining elements to make compounds.
9. Finding out about water and the water cycle.
10. Melting and evaporation experiments.
11. Making solutions and crystals.
12. Using a microscope.
13. Studying cells in a microscope.
14. Learning about reproduction in a flower.
15. Learning about reproduction in animals.
16. Doing experiments with electricity.
17. Doing science experiments by yourself.
18. Doing experiments in a small group.
19. Watching the teacher doing experiments.
20. Looking at science films.

(Hadden and Johnstone, 1983a; p. 316).

What is known about young people's attitudes toward biosciences?

A large qualitative study, undertaken by Lewis *et al.* (1997), utilised card sort activities to elicit knowledge and attitudes toward genetic engineering among young people. In one such activity, students were asked to respond with *'True'* or *'False'* to the following statements:

1. When genes are taken out of animals it is painful for them (False). *Designed to probe student understanding of size and scale and of techniques for obtaining genes.*
2. The genetic code in plants works in quite a different way to the genetic code in animals (False). *Designed to probe students' awareness of the universal nature of codes.*
3. Sheep that produce human insulin have a copy of the human insulin gene in every cell in their body (Potentially True). *Designed to probe students' understanding that a 'foreign' gene would be found in most cells in the animal's body, not just the cells producing human insulin.*
4. Genes are so small that you need special laboratory techniques to separate different genes (True). *Designed to probe students' understanding of scale.*
5. Many hundreds of genes can be coded for in just one strand of DNA (True). *Designed to probe students' understanding of scale and organisation – the relationship between genes and DNA.*

(Lewis *et al.,* 1997; p. 8).

Haste's (2004) study of the values and beliefs related to science among 11 to 21 year olds, sought views on seven distinct aspects of science and scientific research. In the following examples students were encouraged to rate the following statements on a four-point Likert scale of *'Agree strongly', 'Agree slightly', 'Disagree slightly'* or *'Disagree strongly'*, or to make a mark along a continuum to show the extent of agreement to statements:

Benefits of science and technology

1. Science and technology are making our lives healthier, easier and more comfortable.
2. I trust scientists to make responsible judgements about the dangers of their work.
3. Scientific advances are going too far and too fast to be controlled.
4. I trust the government to make any necessary laws to control any dangerous developments in science.
5. Science is largely irrelevant to my everyday life.

Interest in science

Students were asked to demonstrate the extent to which they agreed with opposing statements by ticking one of five boxes to show extent of agreement or disagreement.

I like learning about new developments in technology.	I am not interested in learning about new developments in technology.
I would like to understand a lot more about those areas of science that will affect me personally.	I think I know pretty well all I will ever need to know about the areas of science that will affect me personally.
I like natural history and wildlife programmes on television.	I am bored by natural history and wildlife programmes on television.
I would be interested in a job relating to science.	I would not be interested in a job relating to science.
I enjoy space programmes on television.	I am bored by space programmes on television.
I find programmes about medicine and biology interesting.	I am bored by programmes about medicine and biology.

Concerns about ethics and risks

1. Experimenting on animals is always morally wrong.
2. The media have exaggerated the dangers of GM foods.
3. The likely effects of global warming have been exaggerated.
4. I spend a lot of time thinking about the environment.
5. I spend a lot of time thinking about animal welfare.

Continuing the theme of ethics and risk, students were asked to indicate whether or not they would support the following scientific developments, firstly, if it was shown that they were necessary to obtain nutritionally improved food that tastes and cost the same as food today, and secondly, to achieve new agricultural methods that would significantly benefit the environment:

1. Scientific experiments on live animals.
2. Genetic modification of animals (e.g. in medical research).
3. Genetic modification of plants (e.g. for food stuffs/crops).

(Haste, 2004; pp. 6-7).

Dawson and Taylor's (2000) study of adolescents' bioethical decisions used bioethical dilemmas as the means of eliciting opinions. Dilemmas related to *Cystic fibrosis* and *Huntingdon's disease*. In the following example of a *Cystic fibrosis dilemma,* the bioethical issues related to the paternity of a child. The question for students to decide was *'Do both parents have to know the paternity of the child?'*

Mr and Mrs C come to a genetics clinic for prenatal diagnosis. They have each been tested to determine whether they carry the gene for cystic fibrosis, a hereditary lung disease that causes severe breathing problems. The cystic fibrosis gene is recessive, so a child must inherit a copy from each parent to get the disease. In this case, both Mr and Mrs C are carriers of the cystic fibrosis gene. The specific mutations for each parent were identified in earlier tests.

Mrs C, who is pregnant, undergoes prenatal diagnosis to determine if the foetus is affected. DNA analysis indicates that the foetus does have two copies of the cystic fibrosis gene, but one of the mutations it carries is different to from that of either Mr or Mrs C. That makes it virtually certain that Mr C is not the baby's father.

Should the genetics counsellor tell both Mr and Mrs C about the test results?

(Dawson and Taylor, 2000; p.185)

Stanisstreet *et al.* (1993) explored young people's attitudes toward the use of animals in everyday life and for science. The following questionnaire items were designed to assess attitudes to specific uses of animals. Students were asked to rate statements on a five-point Likert scale including *'Strongly agree', 'Agree', 'Neither agree or disagree', 'Disagree'* and *'Strongly disagree'*:

1. It is wrong to wear leather shoes and jackets.
2. It is wrong to keep animals as pets.
3. It is wrong to experiment on animals for medical research.
4. Intelligent animals should be conserved.
5. We have to eat meat to stay healthy.
6. It is wrong to kills animals to make fur coats.

7. It is wrong to kill fish for our food.
8. It is wrong to eat milk and cheese because these come from animals.
9. It is wrong to use animals in circuses.
10. It is wrong to keep birds in cages.
11. It is wrong to kill animals for our food.
12. It is wrong to kill animals for their skins.

13. Conservation of animals is a waste of time.
14. Farmers have to keep chickens in battery cages so we have enough meat to eat.
15. It is wrong to dissect dead animals for teaching.
16. Beautiful animals should be conserved.
17. All plants should be conserved.
18. The meat from chickens kept in battery cages is not safe to eat.

19. It is wrong to kill crocodiles to make shoes and handbags from their skins.
20. It is wrong to keep animals in zoos.
21. All animals should be conserved.
22. It is wrong to keep chickens in battery cages.
23. It is wrong to test cosmetics (things like lipstick) on animals.
24. We have to cut down rain forests to let us farm and produce food.
25. All insects should be conserved.
26. Circuses make animals look silly.
27. It is wrong to do experiments on live animals.

(Stanisstreet *et al.,*1993; p. 413).

Millett and Lock's (1992) study also focussed on young people's attitudes toward animal use in science, though the questions used to assess attitudes had a slightly different focus. The questionnaire comprised subsets including *Attitudes toward animal experimentation, Attitude toward use of animals on schools* and *Attitudes toward use of animals in farming.* In the following example of one subset of questions, students were asked to rate statements on a three-point scale including *'Agree', 'Uncertain'* and *'Disagree'*:

Attitudes toward animal experimentation

1. New medicines should be tested on animals before they are taken by humans.
2. I believe in a total ban on animal experiments.
3. I would prefer to take medicines that had not been tested on animals.
4. I think that medicines for human use should only be tested on humans.
5. I would take a medicine that had been tested on animals if it would save my life.
6. Deodorants should be tested on animals' skin to make sure they are safe for humans to use.
7. I would stop buying a product if I found out that it had been tested on animals.
8. Research from animal experiments improves the lives of people.
9. I think that no more cosmetic products (like shampoo and lipstick) should be tested on animals.
10. I think that household cleaning products should not be tested in animals.
11. I think that animals should be set free from experimental laboratories.
12. A new washing-up liquid should be tested on animals' skins before being sold in the shops.
13. Medicines used for treating pet dogs should be tested on laboratory dogs first.
14. I think that animals should still be used to research diseases for which there are no cures.
15. Animal experiments only tell us about animals and not about people.
16. I think scientists should find an alternative to animal experiments.

(Millett and Lock, 1992; p. 206).

What can be learned from international comparative studies?

The international Relevance of Science Education (ROSE) project utilises detailed and comprehensive questionnaires designed to assess young people's attitudes toward science. The questionnaire is divided into seven sections:

- What I want to learn about.
- My future job.
- Me and the environmental challenges.
- My science classes.
- My opinions about science and technology.
- My out-of-school experiences.
- Myself as a scientist.

While the questionnaire is too extensive for inclusion in its entirety, examples of each section provide a clear indication of the range of questions included.

What I want to learn about

Students were asked to tick a box on the four-point continuum from *'Not interested'* to *'Very interested'* in response to the following science topics:

1. Stars, planets and the universe.
2. Chemicals, their properties and how they react.
3. The inside of the earth.
4. How mountains, rivers and oceans develop and change .
5. Clouds, rain and the weather.
6. The origin and evolution of life on earth.
7. How the human body is built and functions.
8. Heredity, and how genes influence how we develop.
9. Sex and reproduction.
10. Birth control and contraception.
11. How babies grow and mature.
12. Cloning of animals.
13. Animals in other parts of the world.
14. Dinosaurs, how they lived and why they died out.
15. How plants grow and reproduce.
16. How people, animals, plants and the environment depend on each other.
17. Atoms and molecules.
18. How radioactivity affects the human body.
19. Light around us that we cannot see (infrared, ultraviolet).
20. How animals use colours to hide, attract or scare.

My future job

1. Working with people rather than things.
2. Helping other people.
3. Working with animals.
4. Working in the area of environmental protection.

5. Working with something easy and simple.
6. Building or repairing objects using my hands.
7. Working with machines or tools.
8. Working artistically and creatively in art.
9. Using my talents and abilities.
10. Making, designing or inventing something.
11. Coming up with new ideas.
12. Having lots of time for my friends.
13. Making my own decisions.
14. Working independently of other people.
15. Working with something I find important and meaningful.
16. Working with something that fits my attitudes and values.
17. Having lots of time for my family.
18. Working with something that involves a lot of travelling.
19. Working at a place where something new and exciting happens frequently.
20. Earning lots of money.

Me and the environmental challenges

1. Threats to the environment are not my business.
2. Environmental problems make the future of the world look bleak and hopeless.
3. Environmental problems are exaggerated.
4. Science and technology can solve all environmental problems.
5. I am willing to have environmental problems solved even if this means sacrificing many goods.
6. I can personally influence what happens with the environment.
7. We can still find solutions to our environmental problems.
8. People worry too much about environmental problems.
9. Environmental problems can be solved without. big changes in our way of living.
10. People should care more about protection of the environment.
11. It is the responsibility of the rich countries to solve the environmental problems of the world.
12. I think each of us can make a significant contribution to environmental protection.
13. Environmental problems should be left to the experts.
14. I am optimistic about the future.
15. Animals should have the same right to life as people.
16. It is right to use animals in medical experiments if this can save human lives.
17. Nearly all human activity is damaging for the environment.
18. The natural world is sacred and should be left in peace.

My science classes

1. School science is a difficult subject.
2. School science is interesting.
3. School science is rather easy for me to learn.
4. School science has opened my eyes to new and exciting jobs.
5. I like school science better than most other subjects.

6. I think everybody should learn science at school.
7. The things that I learn in science at school will be helpful in my everyday life.
8. I think that the science I learn at school will improve my career chances.
9. School science has made me more critical and sceptical.
10. School science has increased my curiosity about things we cannot yet explain.
11. School science has increased my appreciation of nature.
12. School science has shown me the importance of science for our way of living.
13. School science has taught me how to take better care of my health.
14. I would like to become a scientist.
15. I would like to have as much science as possible at school.
16. I would like to get a job in technology.

My opinions about science and technology

1. Science and technology are important for society.
2. Science and technology will find cures to diseases such as HIV/AIDS, cancer, etc.
3. Thanks to science and technology, there will be greater opportunities for future generations.
4. Science and technology make our lives healthier, easier and more comfortable.
5. New technologies will make work more interesting.;
6. The benefits of science are greater than the harmful effects it could have.
7. Science and technology will help to eradicate poverty and famine in the world.
8. Science and technology can solve nearly all problems.
9. Science and technology are helping the poor.
10. Science and technology are the cause of the environmental problems.
11. A country needs science and technology to become developed.
12. Science and technology benefit mainly the developed countries.
13. Scientists follow the scientific method that always leads them to correct answers.
14. We should always trust what scientists have to say.
15. Scientists are neutral and objective.
16. Scientific theories develop and change all the time.

My out-of-school experiences

1. Tried to find the star constellations in the sky.
2. Read my horoscope (telling future from the stars).
3. Read a map to find my way.
4. Used a compass to find direction.
5. Collected different stones or shells.
6. Watched (not on TV) an animal being born.
7. Cared for animals on a farm.

8. Visited a zoo.
9. Visited a science centre or science museum.
10. Milked animals like cows, sheep or goats.
11. Made dairy products like yoghurt, butter, cheese or ghee.
12. Read about nature or science in books or magazines.
13. Watched nature programmes on TV or in a cinema.
14. Collected edible berries, fruits, mushrooms or plants.
15. Participated in hunting.
16. Participated in fishing.
17. Planted seeds and watched them grow.
18. Made compost of grass, leaves or garbage.
19. Made an instrument (like a flute or drum) from natural materials.
20. Knitted, weaved, etc.

Myself as a scientist
Assume that you are grown up and work as a scientist. You are free to do research that you find important and interesting. Write some sentences about what you would like to do as a researcher and why.

I would like to . . . .
Because . . . .
The ROSE project 2004