Science, Technology and Society in Science Education

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Preface

In South Australia, the shift towards emphasising the relationships between science, technology and society (STS) to students in science classes has sought to enable students to deal responsibly with the many STS issues that affect their lives.

This study had four major purposes.

First, the study developed and used scales to measure the strength and coherence of students', teachers' and scientists' views, beliefs and attitudes in relation to STS. The consistency of the views of students was established using Rasch scaling. The scales assessed views on: (a) Society, (b) Science, and (c) Scientists. Second, the factors, which influenced the development of strong and coherent views on STS by students, were examined. Third, the study investigated whether male and female students differed in the strength and coherence of their views on STS. Fourth, structured group interviews with teachers provided information for the consideration of the problems encountered by teachers and students in the introduction of STS courses.

The strength and coherence of teachers' views on STS were higher than the views of scientists, which were higher than those of students on all three scales. The range of STS views of scientists, as indicated by the standard deviation of the scores, was consistently greater than the range of teachers' views.

Student-level factors which were shown to have a significant effect on the strength and coherence of students' views on STS were:

(a) science subject studied,

(b) liking of science,

(c) perceived academic performance in science,

(d) socioeconomic status of student's home,

(e) expectations of further study,

(f) expected courses for further education,

(g) expected future occupations, and

(h) socioeconomic status of school.

Limited evidence was found of school-level factors influencing differences between schools with respect to students' views on STS.

Female students had stronger and more coherent view on STS than male students on all three scales. There were significant differences between the views of male and female students on issues that related to the human element of science. There were no significant differences between male and female students' expectations of further study of science after school.

A large number of teachers viewed the curriculum shift towards STS positively. These were mainly the younger teachers, who were enthusiastic about teaching the issues of STS. Some of the teachers focused predominantly upon covering the content of courses in their classes rather than discussing STS issues. Unfortunately, it was found in this study that a significant number of teachers had a limited understanding of both the nature of science and STS issues.

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I am also indebted to the Flinders University of South Australia for providing a HECS scholarship for the duration of the study; the South Australian Department for Education and Children's Services and principals of numerous government and non-government schools in South Australia for granting permission to administer the instrument in the schools; the many teachers who allowed access to their students and who were prepared to share their time to participate in interviews; and the many parents who gave permission for the students to participate in this study.

My sincere thanks also go to the Australian Science Teachers' Association for supporting my application for a UK/Australia Exchange Fellowship to visit the United Kingdom.

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Issues Confronting Science Education

The modern world is increasingly dependent upon science and technology. The growing impact of science and technology on the lives of citizens in contemporary societies is evidenced by value-laden scientific and technological issues. These issues include: acid rain, the greenhouse effect, the use of nuclear power, desertification, the products of genetic engineering, and advances in reproductive technology such as *in-vitro* fertilisation (IVF). The social impact of these scientific and technological issues demands public attention, and is increasingly the subject of media attention and political discussion (National Science Board, 1990).

Education for Increased Public Understanding

In order to shape a sustainable future by using scientific knowledge and improved technology, there are a number of dimensions of the relationships between science, technology and society (STS) that need to be addressed by science and technology education. First, social factors shape technological problems as well as the pace and direction of scientific advance. It is also extremely important to recognise that science provides the knowledge base for technology and dominates the culture of developed nations, while technology provides the tools for science and shapes social networks (Lowe, 1995). Consequently, as many eminent researchers have argued (Bybee, 1987: Cross, 1990; Yager, 1990a, b; Heath, 1992; Lowe, 1993), public debate and consideration of issues with respect to the relationships between science, technology and society are necessary in order to develop national policy to guide the use of science and technology in contemporary and future societies. Public understanding of the relationships between science, technology and society is necessary for citizens to engage in informed debate on the use of science and technology in society. Scientific and technological knowledge has immense potential to improve the lives of humans in modern societies if the imparting of this knowledge is accompanied by open public debate about the risks, benefits and social cost of scientific and technological innovations (Gesche, 1995).

Public Understanding of Science in Australia

Immediately after World War 2 and the dropping of the atomic bombs, Conant (1947) foresaw the situation where people would feel alien, lost and threatened by the awesome power of science. He proposed that this problem could be largely alleviated by the widespread promotion of an understanding of science. As Conant suggested, once scientific ideas were assimilated by people, the people would no longer feel lost or confused, and an understanding of science would become an element of strength.

Public debate in relation to the use of science and technology in society requires an effective understanding of the issues of STS. A report on a survey of the attitudes of the Australian people to science and technology by the Commission for the Future concluded that Australians regarded science and technology as important, but felt threatened by their growing and seemingly uncontrolled power. The report stressed that if Australian people wanted to create a future that young people could look forward to, much more attention needed to be given to the uses and consequences of science and technology (Eckersley, 1988).

There is a need for community awareness in Australia that the future is not pre-determined but a product of human decisions and actions, since decisions about science and technology help to shape the future. Significant reform of the school curricula is necessary in order to equip students with the skills and knowledge that they need to contribute to informed public decisions. If science is presented by teachers in schools as a series of emerging theories, rather than a set of eternal truths and universal laws, and students grapple with the complex problems of the real world, they are more likely to be prepared for lifelong learning and their future working lives (Lowe, 1990).

Science curricula with an STS focus prepare students both to use technology in their own lives in an increasingly technological world and to deal responsibly with social decisions relating to science and technology (Cross, 1990; Yager, 1993).

Recognition of this need has resulted in changes in the aims and objectives of science education in Australia, and more specifically in South Australia in recent years. The South Australian Certificate of Education (SACE) syllabi in science (Senior Secondary Assessment Board of South Australia [SSABSA], 1991a) adopted in South Australia in 1992, and the National Statements and Profiles (Curriculum Corporation, 1994 a, b) which were introduced in 1994 are evidence of a major shift in the science courses to include objectives related to STS.

World-Wide Recognition of the Need for a New Model of Science

The world-wide demand for changes in education and a shift in the emphasis of science courses in order to equip students for their lives in a technology-permeated society has led to a global revolution in science, technology and mathematics education. In many countries, there have been considerable efforts made to forge lasting educational reforms in the rapidly changing subject areas of science, technology and mathematics (*Education Week*, April 10, 1996, p. 1). These innovative reforms have been occurring at an unprecedented rate around the world. The Organisation for Economic Cooperation and Development (OECD) began an extensive investigation to obtain information about how science, technology and mathematics education were changing in its member countries, since every OECD country was trying to make changes in the way in which these subjects were taught. The OECD case studies analysed efforts to change the focus of learning in science, technology and mathematics subjects from pure knowledge of subject matter to practical applications, with closer connections to students' everyday lives. These changes towards the presentation of a different model of science were driven both by serious concerns about the economic competitiveness of these countries, and distress about social and community-based issues, such as environmental deterioration. The drive was also fuelled by a desire to make science and mathematics content correspond more closely to what practising scientists really did, and to what scientists actually studied (*Education Week,* April 10, 1996, p. 2).

A different model of science, which focused on the use of science as part of everyday life in society, was presented in Yokohama City in *Case Studies of the Implementation of a New Science Course in Japan*. Students learnt of the possible ways of mitigating the harm caused by acid rain. In American schools which used *Chemistry in the Community: a Science Education Curriculum Reform,* knowledge of chemistry was presented as being crucial in preventing or lessening environmental damage due to toxic chemical spills. This model of science emphasised social relevance, interest and decision-making by students (*Education Week*, April 10, 1996, p. 5).

It is of importance for this present study that the suggestion has been made that in order for science education to have a positive influence on the limitation of environmental damage caused by acid rain, by way of example, an understanding of other factors which are involved in the interaction between science, technology and society is necessary. These factors include community reaction to the challenge of reducing pollution, the influence of different interest groups, and public policies about environmental protection. Awareness of the influence of the interaction between these social factors and the development and use of science and technology in society is furthered by science education which presents a different model of science by including discussion of the issues of STS.

Australian Studies on Science and Technology Education

In 1993, on behalf of the Minister for Employment, Education and Training, the Australian National Board of Employment, Education and Training (NBEET) contracted the Commission for the Future to undertake a background study of underachievement in science and technology education. One of the findings of this inquiry that is significant for this present study is the recognised need to emphasise to students the application of the scientific and technological concepts to real world situations. Furthermore, the NBEET study found that most Australians had a limited or confused understanding of the nature of science and its relevance to society. Educational strategies to broaden public knowledge of the relationships between science, technology and social change were recommended. It was also acknowledged that underachievement in science and technology among females was of great concern, and needed to be addressed to further greater achievement in science and technology in Australia (NBEET, 1993).

At the conclusion of this NBEET study, the recommendation was made by the Commission for the Future that there was a need to define the kind of science learning that would provide the educational basis for the national statements or curricula that should be developed. It was argued that:

> ..the most important factor giving rise to underachievement in science and technology is that students and teachers are not being made aware of the real nature of science and technology as practised in the everyday world, and of the real nature of technological careers and the people who pursue them. (NBEET, 1993, p. 35)

The report continued with a discussion of the thrill of scientific inquiry, which was equated with detective fiction, and the satisfaction that resulted from working to solve societal or environmental problems. It was suggested that it was necessary to involve students in scientific and technical projects that were "embedded in a social context that closely approximated the real-life interaction of science and technology with society" (NBEET, 1993, p. 35).

Advice on the provision of quality science education in Australian schools was presented in a later publication in response to the recommendations of this study by the Commission for the Future. In this more recent publication, the need to appreciate the social implications of science and technology was also recognised, and it was acknowledged that science education was a lifetime requirement for all (NBEET, 1994). Moreover, the need to increase participation in science and technology at all levels among women, as well as other groups was emphasised. The suggestion was made that gathering base line data that monitored current outcomes for people in these groups might enable identification of areas where the development of initiatives was indicated (NBEET, 1994). This call for base-line data for women in relation to the shift towards STS in upper secondary school science courses in South Australia needs to be addressed in this study.

The vital role of science teachers in the development of the future community's attitudes towards science and technology was another issue identified in this report by NBEET. In addition to passing on inaccurate information, a teacher with inadequate knowledge might, unfortunately, transmit incorrect understandings of science. Since science teachers' understandings enable them to teach confidently and deliver the curriculum in interesting and stimulating ways, it was suggested that appropriate enhancement of teachers' skills should both take place at the pre-service stage and be provided as professional development for practising teachers. The need for the enhancement of teachers' understandings in relation to STS clearly should be investigated. The findings of an investigation might, as a consequence, form the basis for the development of appropriate and effective programs of professional development for teachers.

However, the authors of this report believed that most of the government effort to improve the quality of science education in Australian schools had been devoted to national standard setting or curriculum reform, which had merely resulted in trying to teach more content in less time. Consequently, students learnt a large amount of low quality material. The significant conclusion reached was that instead of such an outcome of science education, students should develop an appreciation of the role of science and technology in their everyday lives (NBEET, 1993, p. 11). Thus an investigation of the strength and coherence of students' views about science, technology and society is important.

STS Education for Informed Public Discussion

The inclusion of studies in STS in Australian senior secondary science courses would help to alleviate the problem of people viewing science and technology as a threat. Once students understood the relationships between science, technology and society and had developed greater confidence in their own moral decision-making, they would be able to play a more active role in debates on STS issues without feeling threatened by the power of science and technology.

Science courses that helped students to link theoretical ideas with practical situations, human concerns and their lives outside the classroom would assist students in Australia to grow to be in charge of the decision-making processes that shape their lives (Malcolm, 1992a). A study in England by Durant, Evans, and Thomas (1989) found that respondents who were better informed about science possessed a generally more supportive view of science. This support was, however, for more obviously useful science and technology, such as more powerful computers, rather than for those developments in science and technology, such as human embryo experimentation that involved a moral challenge.

It is significant for the purposes of this work that in an analysis of Australian data, a greater awareness of both the beneficial aspects and the non-harmful aspects of science were found to be related to greater knowledge of science (Keeves and Morgenstern, 1992). Consistently positive relationships between science achievement and the science attitudes of interest in science, ease of learning science and career interest in science have also been reported by Keeves and Morgenstern (1992). The authors concluded that more knowledge in science was, in general, related to more favourable attitudes and values towards science.

A realistic attitude towards STS entails both an appreciation of the limitations of science and technology to solve social problems and strong and coherent views, beliefs and attitudes towards science and technology. It is necessary to consider whether science in senior secondary schools in Australia is being taught in a manner that enables students to develop strong and coherent views, beliefs and attitudes towards STS. Consequently research is required in upper secondary schools in Australia that is concerned with the strength and coherence of Australian students' views, beliefs and attitudes in relation to science, technology and society.

Views, Beliefs and Attitudes Towards STS

An assessment of students' views, beliefs and attitudes in relation to STS is necessary to guide and inform the development of courses and curricula. In a report by Ziman (1980), attention was drawn to the need for further research into personal characteristics, such as attitudes, beliefs and values, as well as societal influences, such as education and the media, on the development of an understanding of science and technology.

Measuring Students' Views, Beliefs and Attitudes Towards STS

A study of science education in 19 countries including Australia in the early 1970s (Comber and Keeves, 1973) for the International Association for the Evaluation of Educational Achievement used a test which drew heavily upon the Test on the Understanding of Science (TOUS) (Cooley and Klopfer, 1961) in order to assess students' ability to understand the nature and methods of science. It was considered that the abilities called into play in responding to the items used in the test might bear some relationship to attitudes (Comber and Keeves, 1973).

The problem with these traditional instruments to determine students' understanding of science is that they are based on the erroneous assumption that students interpret the statements included in the instruments in the same way that researchers do (Aikenhead and Ryan, 1992). Munby (1982) termed this problem of students not fully comprehending the meaning of statements in such instruments as "the doctrine of immaculate perception" (Munby, 1982, p. 207). In order to overcome this problem, the *Views On Science, Technology and Society (VOSTS)* questionnaire (Aikenhead and Ryan, 1992) was developed to reduce ambiguity by using the responses of thousands of Canadian Year 12 students to statements on STS issues.

As a consequence, in this present study it was considered that the best instrument to collect students' STS views would comprise a selection of VOSTS items adapted for Australian conditions.

Australian Students' Views and Understandings of Science

Measuring the views of Australian students as a group requires that the students' views are coherent, and the major question remains as to whether students hold coherent views on STS issues. Hence, another important question for investigation is whether students have coherent views on STS issues. A previous Australian study which investigated students' science beliefs (Doig and Adams, 1993), also operated on the assumption that students' views were coherent. However, the ideas and relationships associated with STS issues in the present study are rather more complex than the beliefs considered in the 1993 study.

It is significant that an Australian Science Teachers' Association study in 1994 with students at the beginning of their years at secondary school found that a large majority of the students had positive attitudes to science. These students believed that science was a subject for everybody, as well as being socially relevant and useful for problem solving. However, these positive images of science were said to be formed more from information gained from the media and from outside school, rather than from experiences at school (NBEET, 1994). Nevertheless, in a report prepared in Australia by the Commission for the Future it was concluded that students would continue to avoid further studies and careers in science and technology unless they were seen as attractive options (NBEET, 1993). There is a need to increase the numbers of students choosing to pursue further studies in science, since the applied research performed by graduates of courses in science and technology would produce goods that could be translated into capital (Barnes, 1985). The importance for Australia of developing a strong, active applied science centre that would be able to capture the commercial benefit of its achievements has been argued strongly in government publications over the past five years (Commonwealth of Australia, 1995).

This need for a greater number of students choosing to pursue further studies and careers in science, as well as the need for all citizens involved in decision-making on STS to be able to improve their lives in modern society by dealing responsibly with STS issues which affect their lives (Yager, 1990b; Cross and Price, 1994; Gesche, 1995), have highlighted the need for investigation of the efficacy of students' and teachers' responses to new science courses which include STS objectives. Thus, an Australian study is required that examines students', teachers' and scientists' views towards STS. Furthermore, the inclusion of STS objectives in senior secondary science courses in South Australia is a fairly recent phenomenon, and these developments have not as yet been evaluated.

Gender and STS Views

The findings of research on students' attitudes and values towards science (Johnson, 1995) have pointed to the need to develop a better understanding of the way in which schools and society shape the views and attitudes developed by students. Furthermore, with the changes that have also occurred in the education of girls in science and mathematics in Australian schools since the mid-1970s, it must be anticipated that sex differences in educational outcomes would also be changing over time.

In 1998, with these different expectations and opportunities for girls and the new senior secondary science curricula in South Australia, which emphasise STS objectives, it is important to determine if views, attitudes and values of students towards science are gender-dependent.

Teachers' Views on STS

In any investigation of the inclusion of STS in secondary science courses it is also important to investigate teachers' views towards STS issues. Research has indicated that the views of teachers in relation to aspects of the science curriculum influence the success of these aspects of the curriculum, since teachers only teach well what they understand thoroughly (Lederman, 1986). In the discussions on STS issues at the Fourth International Organisation for Science and Technology Education in 1987, it was concluded that the main obstacle to the implementation of STS courses was the science teacher, since it was clear that the traditional training of teachers rarely touched upon the teaching of an STS course or an STS issue (Hofstein et al. 1988).

The successful implementation of a curriculum innovation requires changes in understandings and beliefs in relation to that particular innovation as well as changes in teaching practices and teaching styles. Professional development and in-service education in support of specific innovations are also vital for the successful implementation of the changed curriculum (Fullan, 1992). The suggestion was made by Fullan (1992) that the first step that needed to be taken when a curriculum shifted towards STS should be to evaluate the beliefs of teachers. This would precede professional development to increase teachers' understanding and therefore competence in this area (Carre and Carter, 1990).

Further support for this suggestion, that it is important to examine the beliefs, opinions and understandings of teachers in relation to the curriculum change, has been provided by a recent OECD study. At the onset of such a curriculum change, teachers, who already have vastly changing roles in the classroom, are required to reassess their traditional classroom practices and teaching methods carefully. These teachers may then feel uneasy about their level of understanding of the new subject matter, and refuse to cooperate with a curriculum change which requires them to take on more demanding roles. While some teachers value the challenge and educational opportunities presented by the shift in objectives of the curricula, others object strongly to such a change. The success of such a curriculum change therefore requires the provision of opportunities for both in-service and pre-service professional development and for regular collaboration with supportive colleagues (*Education Week*, April 10, 1996, p. 7).

In Australia, the Commission for the Future summarised the need for in-service and pre-service education of teachers in relation to science and technology with the suggestion that even with the best possible curriculum, students do not participate more effectively unless it is delivered by teachers who instil enthusiasm by their interest in the subject. The further suggestion was advanced that unless improved in-service and pre-service education were provided for teachers, students would continue to move away from science and technology at both the secondary and tertiary levels (NBEET, 1994).

The importance of a comparison of the beliefs of scientists and teachers has also been emphasised, since the literature contains conflicting opinions, and there is doubt whether philosophers, scientists and science teachers share the same beliefs and views (Pomeroy, 1993). It is significant for this study that the gap in the research on possible differences between scientists' and teachers' views of the nature of science and the scientific method was identified during the interpretation of the findings of a British study (Pomeroy, 1993) which compared science teachers' and scientists' views.

The Need for Evaluation of Change

Evaluation studies are necessary to enhance the appropriateness and effectiveness of educational changes in relation to teaching for the enhancement of student learning. It is difficult to maintain improvement in the quality of learning and teaching without evaluation (Connole, Smith and Wiseman, 1993). Kemmis (1982) suggested that the purposes of evaluation were to confirm and amend educational practices by organising and assembling information and ideas. These ideas and information enable scholarly reflection and debate about what constitutes quality teaching and learning. Central to the evaluation process is reflection in order to construct understandings that inform and rationalise actions. Thus, evaluation is a way of enabling reflection and the identification of courses of action that might be undertaken to increase the chances of success of the move towards the inclusion of STS objectives in secondary science curricula in South Australia. Evaluation must be based upon firm evidence, and the measurement of students' views of STS is required in order to provide such evidence. Furthermore, discussions with teachers are necessary in order to collect their views in an environment in which they may discuss their opinions freely.

Issues of Scale Validity and Internal Consistency

It is important to determine the validity of the instruments used in this study for the measurement of students', teachers' and scientists' views in relation to STS. Moreover, it is necessary to have accurate measurement for any comparison of the strength and coherence of students', teachers' and scientists' views in relation to STS. The accuracy of the findings from studies which employ instruments to gather respondents' views clearly depend upon whether the instruments measure what they are supposed to measure (Connole, Smith and Wiseman, 1993). In addition, the consistency of the scales must be examined to determine whether the items in a scale lie along the underlying dimension that was hypothesized.

Importance of the Study

This investigation comprises a detailed examination of the inclusion of the study of science, technology and society (STS) issues into senior secondary science courses. The purpose of this study is to investigate a curriculum reform that has the potential to change science education markedly and to motivate students, while addressing gender imbalance in science education. The inclusion of STS objectives in science courses draws upon the knowledge and skills from the wider curriculum statements such as the SACE documents and the National Statement and Profiles for science, which contain specific objectives and profile level outcomes related to STS. Science curricula, which include consideration of the issues of STS, seek to develop scientific literacy and prepare students to act as vital participants in a changing world in which science and technology are all pervasive. As Parker, Rennie and Harding have argued, the move toward the provision of "science for all" reflects the aims of science education which include:

> (1) ..to educate students for careers in science and technology; and (2) to create a scientifically and technologically literate population, capable of looking critically at the development of science and technology, and of contributing to democratic decisions about this development. (Parker, Rennie and Harding, 1995, p. 186)

Fensham (1990) has also supported the move to include STS issues into science courses. He wrote that in a "science for all" approach to science teaching, it was important to include STS in order to prepare students for their future lives in society.

This "science for all" approach advocated by Fensham was both a timely and socially-responsive change and in sharp contrast to the former "elite science" for the selected few who went on to be doctors or scientists. Furthermore, in the present Australian society with high levels of youth unemployment and a greater retention rate for upper secondary school students, this STS curriculum focus would appear to be more relevant for the needs of a large proportion of the upper secondary school students.

In order to investigate these new curricula which include STS objectives, there is a need for information to be obtained in regard to: (a) the provision of effective in-service education; (b) the writing of courses, curricula and teaching resources; and (c) the planning of future curriculum developments. It was considered in this present study that this information would best be provided by the development and use of scales to measure students', teachers' and scientists' views on STS. The development of these scales and demonstration in this study that they were able to be used to provide a valid measure of respondents' views on STS represents a significant advance in the area of quantitative educational research in the field. The development of these scales is discussed in detail in Chapter 7, and the theoretical implications of this aim are discussed in Chapter 14.

The study was located in the schools of South Australia at the terminal secondary school level. South Australia was chosen as the location of the study, not merely for convenience but also because the new courses introduced by the Senior Secondary Assessment Board of South Australia in 1993 and 1994 at Years 11 and 12 respectively included a substantial new STS orientation. Thus the study was undertaken in a school system at the initial stage of reform with the introduction of new science curricula.

Overview of the Study

In the introductory chapters of this study the changing perceptions of science and of science education are reviewed before examining students' and teachers' views, beliefs and attitudes towards science, technology and society in later chapters. The discussion in Chapter 2 focuses upon the changing view of the philosophy of science and its educational implications. A review of the worldwide shift towards STS in science education in Chapter 3 traces the history of the development of STS courses. The educational research on the STS approach to science teaching during the past 30 years is surveyed in order to determine important issues for investigation. The factors contributing to the recognition of the need to include discussion of STS issues in science classes are discussed. This account culminates in the debate on the inclusion of STS objectives in secondary science courses in South Australia.

The presentation of the theoretical perspectives for this study in Chapter 4 involves consideration of the nature of science and STS issues as well as the nature of the aspects of the affective domain assessed in this study. The factors that determine the success of curriculum innovations such as the shift towards STS are also discussed. In Chapter 5, the methods used in this present study are considered. The unique features of the design and methodology of this study that enable it to make an original contribution to knowledge in the area of educational research are introduced.

An examination of the literature relating to the items in the scales used in this study in order to validate the scoring of the responses to these items in the initial scales forms the basis of Chapter 6. The second method of validation of the scales, by comparison of the initial scaling with the views of a panel of experts, is described in Chapter 7. A detailed discussion of the development of the three scales to measure views on STS is considered in Chapter 7.

The analyses presented in Chapter 8 examine the factors affecting the strength and coherence of students' views on STS. In Chapter 9, the discussion focuses around the employment of hierarchical linear modelling (HLM) to examine the effects of multi-level variables on the student learning outcomes of strong and coherent views on STS, liking of science and expectations of further science study. The rationale underlying multi-level analysis is discussed in non-technical terms.

The strength and coherence of the STS views of male and female students are shown in Chapter 10. Chapter 11 is based on a comparison of the views on selected STS issues of young people in this South Australian study with the views of both another group of young Australians and the group of young Canadians in the original VOSTS study. The teachers' views, understandings and concerns in relation to the curriculum shift towards STS in South Australia are presented in Chapter 12 in a discussion of the qualitative component of this present study, the structured interviews with teachers.

A discussion of answers to three of the research questions that guided this study is presented in Chapter 13. This discussion of some of the quantitative findings of the study focuses on the major aim of this study, to develop and use scales to measure and compare the strength and coherence of students' views on STS. In the final chapter, Chapter 14, the results of all analyses are considered from the broader perspective of the research questions.

2

STS: A New Challenge for Science Education

The need to present a revised view of science which emphasises the interaction between science, technology and society (STS) to students and citizens in Australia is discussed in Chapter 1. The STS view of science has been accepted gradually by scientists and educators, and a worldwide shift or reorientation towards the inclusion of STS objectives in secondary science classes has evolved. The impetus for the changing perception of science and reorientation of science curricula has been due to the writings of many scholars, including Conant (1947), Kuhn (1963), Lakatos (1970), and Popper and Eccles (1977). Their publications and theories about the nature and philosophy of science have changed understandings of the nature of science. Several decades later, these ideas are finding their way into secondary education. In this chapter, the work of these and other eminent scholars provides an introduction to modern views of the nature of science.

The Philosophy of Science

Science has become a preponderant part of the knowledge base upon which humans draw to understand and explain the world around them. The products of science are the equipment and appliances surrounding citizens of modern societies, and science has come to be considered by humans as one of the most valuable kinds of knowledge (Ziman, 1968). In light of the high regard for science by many members of modern societies, it is important to ask what distinguishes scientific knowledge from superstition, ideology or pseudoscience? The struggle between science and the ruling ideology throughout history is exemplified by the opposition to the work of Copernicus mounted by the Catholic Church. The demarcation between science and ideology is not merely a philosophical problem, but a problem with vital social and political relevance.

Moreover, if, as the philosopher Kuhn (1970a) has suggested, it is difficult to know that a newly-accepted scientific theory is better than a preceding one, then the implications for science education are substantial, in so far as a selection must always be made with respect to what is to be taught in schools. Consequently it is important to consider both changes in philosophical and epistemological models of science as well as the educational implications of this changing picture of science.

The Changing Perceptions of Science

Conant's work in the 1940s on the nature of science is arguably the most significant interpretation of science in the post-war decades, particularly with respect to views of STS education. Conant (1947) discussed science as a human activity which is neither benign nor malignant but which has several "cracks". He continued by suggesting that the atomic bomb was evidence of these cracks. Conant's conclusion was highly significant for science education and educational research in the post-war era of the 1950s. As Conant stressed:

> ..whether we have courage enough to face the most recent evidence of this "fatal flaw" and intelligence enough to proceed with the next stage in the development of civilisation will in part depend on education. This fact in itself would be justification enough for all of us who spend our lives trying to explore new and better ways of "perpetuating learning to posterity". (Conant, 1947, pxiii)

The interrelationship between science, technology and society was emphasised repeatedly in Conant's works, and he believed that the study of the history of science illustrated the growth of science as an organised social activity (Conant, 1947). The author's great insight was displayed in his view that an understanding of the methods by which science had advanced would provide a basis from which citizens could appraise proposals for research and the applications of this research. Conant's case histories in science showed that throughout history, science had been affected profoundly by values, religious factors, economic conditions and social factors such as class structures. The definition of science given by Conant is that:

> ..science is a process of fabricating a web of inter-connected concepts and conceptual schemes arising from experiments and observations and fruitful of further experiments and observations. (Conant, 1952 p. 62)

However, it is important to note that the author hastened to add, "the activities of scientists in their laboratories are shot through with value judgments" (Conant, 1952, p. 62). This view of scientific advance being directed by the value judgments of individual participants is valid, since when working in the laboratory, as Conant noted, the scientist is constantly making judgments of what course of action or what experiment is worth pursuing, and these decisions involve value judgments.

The Epistemology of Science

Conant's views on the strong influence that the attachment of scientists to some scientific theories had on the advance of science were shared by Kuhn. When Conant was President of Harvard University his work on the history of science inspired Kuhn and thereby initiated a dramatic change in Kuhn's conception of the nature of scientific advance. Kuhn (1970a) suggested that "normal science" consisted of research based on past scientific achievements that received sufficient support from the scientific community to provide models for further scientific work. These models, or accepted examples of scientific practice, included law, theory, application and instrumentation, and Kuhn referred to them as "paradigms". Students were prepared for membership of the scientific community by studying the paradigms they would later practise. In Kuhn's model of the scientific method, research in a particular field necessitated a commitment to the rules and standards of practice prescribed for that branch of science.

When a paradigm ceased to explain all of the observations and would not stand up to testing, there was a transition to another conceptual scheme, or paradigm, through a "scientific revolution" (Kuhn, 1970a). Kuhn maintained that this was the characteristic developmental pattern of mature science. Paradigm change was radical, and Kuhn believed that paradigms were "incommensurable" and the progress of change from one paradigm to another was not entirely logical. Conant (1957) suggested that a new conceptual scheme was accepted because it was at least as satisfactory as, or more satisfactory than, the old one in explaining the facts, and proved more productive of new experiments. Once a scientific community accepted a paradigm it also gained criteria for choosing problems that could be assumed to have solutions, but only as long as the paradigm was accepted. To a large extent, these were the only problem-solving exercises that the community would encourage its members to undertake (Kuhn, 1970a).

The idea that a paradigm guided research conducted by scientists was shared by Polanyi (1969). As Polanyi suggested, such a view of the scientific method entails the presumption that any evidence that disagrees with the existing paradigm is invalid. Thus any deviant evidence is then discarded, even if it could not be explained. This is a dangerous practice, but the scientific community protects itself by allowing some difference of opinion.

The concepts of the paradigm and normal science proposed by Kuhn have significant implications for education. Kuhn (1970a) wrote that after the transition to a new paradigm scientists must be re-educated in their perceptions of nature so that they are able to see things in a different way. After this has been accomplished, the scientist's new world of research would seem incommensurable with the previous one. Kuhn stressed that the observations and measurements that a scientist undertakes in the laboratory are not, therefore, what a scientist sees, but concrete indicators for the elaboration of an accepted paradigm. He argued that since it was difficult to make nature fit a paradigm, the puzzles of science were extremely challenging (Kuhn, 1970a).

Kuhn was a practising scientist before he became a philosopher and historian of science, and his work displays an accurate awareness of the ways in which scientists work. An unsubstantiated aspect of Kuhn's work arises from his notion of the incommensurability of paradigms, since it is not clear how it is possible to progress closer to a more valid picture of nature by changing from one paradigm to another. Kuhn's view of science contrasts markedly with the view of Popper, and other philosophers who suggested that science is essentially a cumulative process.

Feyerabend (1970) agreed with Kuhn in regard to the incommensurability of paradigms since there was no way of knowing that the new paradigm was better than the old. However, Feyerabend believed that the theory of science proposed by Kuhn was disquieting, since it might increase the anti-humanitarian tendencies of modern science. Feyerabend maintained that modern science was an ideology with insufficient concern for humanity. He therefore aimed to expose, demystify and weaken the hold of the scientific ideology.

In a defence, Kuhn (1970b) argued that in his model, scientists were persuaded of the validity or rationality of competing theories by the theories' accuracy, scope, simplicity and fruitfulness. Consequently, there were many good reasons for choosing one theory rather than another. He suggested, however that existing theories of rationality were inadequate and it was necessary to readjust or change them to explain the workings of science. He concluded:

> To suppose, instead that we possess criteria of rationality which are independent of our understanding of the essentials of the scientific process is to open the door to cloud-cuckoo land. (Kuhn, 1970b, p. 264)

Kuhn's work was concerned, primarily, with the growth of scientific knowledge rather than with the validation of particular theories. He was concerned with the factors influencing the acceptance of novel ideas in science, and he suggested that these included historical and sociological factors rather than just logical factors. Kuhn believed that social factors and the ways in which scientists worked in sociological groups influenced the knowledge that was produced. Kuhn (1970a) wrote that, in addition to the breakdown of the normal puzzle-solving activity, social factors contributed to the crisis that led to scientific revolutions. In the evolution of the field of astronomy, which was used by Kuhn as an example, significant social and historical events such as the social pressure for calendar reform, the rise of Renaissance Neoplatonism and medieval criticism of Aristotle helped to precipitate the Copernican revolution. It was, therefore concluded that external factors like those discussed above:

> ..are principally significant in determining the timing of the breakdown, the ease with which it can be recognised, and the area in which, because it is given particular attention, the breakdown first occurs. (Kuhn, 1970a, p. 69)

Feyerabend's (1970) evolutionary model of science was the synthesis of Lakatos's belief that proliferation and tenacity were both always present in science. In this model, development and growth occur as a result of scientists comparing the central paradigm with alternative theories. This comparison features the active interplay of various tenaciously held views. Feyerabend criticised Kuhn for failing to discuss the aim of science. One of his most cogent criticisms of Kuhn, however, was that in Kuhn's normal science when scientists struggle to articulate the paradigm and make it more coherent, they cease to be explorers and develop closed minds. Kuhn suggested, however, that scientific revolutions, or periods in which scientists lost faith in the prevailing paradigm occurred, and in certain circumstances competing theories or paradigms were accepted. It is important to consider the method used by scientists in the formulation of these competing theories.

The Empiricist-Inductivist Model of the Scientific Method

The scientific method has been portrayed traditionally as being ruled by empirical facts and logic (Riggs, 1992). Consequently, it is important to consider the derivation of these scientific facts. The empirical method of science implies that science starts with observation, and the universal statements that make up scientific knowledge are then derived from the singular statements that result from observation by the process of induction. Inductivists claim that:

> ..provided certain conditions are satisfied, it is legitimate to generalise from a finite list of singular statements to a universal law. (Chalmers, 1982, p. 2)

The earlier English scholar, Bacon, suggested that science progressed by this empirical approach, which involved settling questions by direct observations, since proof always required solid evidence (Connole, Smith, and Wiseman, 1993). The empirical method of science comprises the gathering of "facts" by careful observation and experiment, and then deriving laws and theories from those facts by some kind of logical procedure (Chalmers, 1982). Bacon argued that from a sufficiently large number of observations, the method of induction allowed generalisations to be formulated in laws and theories of nature. Bacon's empiricist-inductivist model came to be regarded as an account of the way in which scientific knowledge was processed. These ideas of the epistemology of science were embodied in positivism that dominated philosophy from the seventeenth century until the mid-twentieth century. However, Conant (1957) argued that the method of "pure empiricism" was an ancient method of solving problems by experiment and "let's try and see" reasoning. Although this method had, in Conant's opinion, led to amazing results throughout the years, and was still a part of the modern scientific procedure, its role had been reduced by the activities of scientists in modern pure and applied science.

Logical Positivism and Falsificationism

Inductive reasoning in science features in the philosophical position known as logical positivism. Proponents of logical positivism believe that scientific events are meaningful if they can be verified by observation.

The Australian philosopher, Chalmers (1982), defined logical positivism as:

> ..an extreme form of empiricism according to which theories are not only to be justified by the extent to which they can be verified by an appeal to facts acquired through observation, but are considered to have *meaning* only insofar as they can be so derived. (Chalmers, 1982, p. xviii)

Chalmers advanced a potent admonition of this philosophical position. He wrote that quantum physics and Einstein's theory of relativity could not be explained by logical positivism.

Prior to Charmers' consideration of the nature of the development of scientific understanding, Lakatos (1970) had also argued that Einstein's results convinced many philosophers and scientists that positivism was not a valid view of the philosophy of science. Lakatos further suggested that this whole classical structure of intellectual values fell into ruins and had to be replaced. Lakatos believed that both Popper and Kuhn rejected the notion that evolution of scientific knowledge involved the accumulation of eternal truths. Furthermore, the overthrow of Newtonian physics by Einstein also provided inspiration for both of these philosophers. However, while Popper believed that everyday science was based upon criticism and was somewhat revolutionary by nature, in Kuhn's vision of normal science, revolution was exceptional. The clash between Popper and Kuhn concerned intellectual values. It has been argued that for Popper, scientific change was a rational process rather than what he termed the "religious conversions" that characterised Kuhn's scientific revolutions (Lakatos, 1970, p. 93).

The German philosopher of science, Popper (1983), also refuted logical positivism in a convincing manner. In Popper's view, the problem with positivism was that generalisations made by induction could not be regarded as certain, since they could be overturned by another contrary event. Popper attacked this problem with induction. He criticised and undermined the logical positivists' view of science. Popper concluded that theories could never be conclusively proven by confirmation derived from repeated observations. He concluded that they could, however, be falsified by even one contradictory instance (Connole, Smith, and Wiseman, 1993).

Popper wrote that scientific revolutions were induced by falsification of the theory or paradigm that was currently accepted. A statement or theory is falsifiable if at least one possible basic statement conflicts with it logically. The ideas of Popper and Kuhn as to falsificationism therefore display some agreement. Popper (1983) also believed in the conservative power of the paradigm, since he wrote that it was possible for a falsification to be insufficiently cogent to convince scientists to regard the existing theory as false. Popper contended that scientists then found a way of ignoring the empirical falsification by introducing a subsidiary hypothesis.

However, Lakatos (1970) believed that Popper showed that all theories were equally unprovable. Dogmatic falsificationism was therefore empiricist without being inductivist. Furthermore, Lakatos argued that dogmatic falsificationism was based upon false assumptions. The first incorrect assumption was that there was a natural borderline between theoretical propositions and observational propositions. The second assumption was that if a proposition was observational, then it was true. These assumptions are not entirely correct, as Lakatos asserted, and the implications for the nature of scientific knowledge are discussed below in the section on the theory-dependence of observation. Lakatos (1970) further contradicted the falsificationists' claim that theories were admitted as scientific when they were disprovable. He argued that it was necessary to label scientific theories like those of Newton, Maxwell and Einstein as "unscientific" since they could not be disproven or proven by a finite set of observations.

This refutation of falsificationism was supported by Chalmers (1976) who suggested that the theory-dependence of observation rendered all observations fallible. As a consequence, conclusive falsifications of a theory were not possible. He also suggested that the inductivists did not give a true account of science. Chalmers used the Copernican Revolution as a case study to support his claims, since he asserted that in this case, the concepts of force and inertia arose from novel conceptions to which the proponents continued to adhere despite apparent falsifications. Furthermore, these concepts did not result from observation and experiment. Chalmers (1976) argued that induction and falsification were inadequate accounts of science. Chalmers' suggestion that the theory-dependence of observation undermined the adequacy of the falsificationist account of the nature of science is supported by the argument developed in this chapter.

Popper (1977) asserted that although scientific theories and problems were made by humans, they were not always the result of planned production by individuals. Once theories existed, they produced previously invisible consequences, or problems. It was argued, therefore, that the task of the scientist was to discover the relevant logical consequences of the new theory, and to discuss them in light of existing theories. He further wrote that scientific knowledge is objectively criticisable by arguments and tests. Tests are attempted refutations.

The Objectivity of Science

Since scientific theories are made by human beings, who are subject to the whole range of human weaknesses and fallibilities, as well as strengths and inspirations, it is important to consider the human face of science in this discussion. What are the implications of the views of science as described by Conant, Kuhn, Popper and Eccles and Chalmers for the objectivity of science and the freedom of scientific inquiry? Much has been written about the value-laden nature of science, and the fact that there is not always a free flow of information in science.

Kuhn (1970a) completed his book with the following statement:

> Scientific knowledge, like language, is intrinsically the common property of a group or else nothing at all. To understand it we shall need to know the special characteristics of the groups that create and use it. (Kuhn, 1970a, p. 210)

The STS view of science acknowledges that scientists, as humans, may be influenced by a number of factors when engaged in scientific activities. These factors, or values, which have a profound effect on the direction of science, include: religious views, gender issues, financial concerns such as the pursuit of research grants and rewarding salaries, legal issues, moral issues such as personal views on the violence of wars, and the desire for personal recognition and fame.

Polanyi (1969) argued that since the existence of true human values, which motivate people, was acknowledged, the claim that human actions could be explained without any reference to the exercise of moral judgment was implicitly denied. The assertion that scientists made value-free scientific pronouncements was, therefore proved to be inconsistent. Polanyi concluded that if people explained all their human actions by value-free observations, then none of these persons' actions could claim to be motivated by moral values.

Science certainly is not a totally objective activity and scientists, as humans, cannot be completely objective. Scientists often take one stance or another because they have a particular ideology based on their social position or education. Longino (1983) addressed the question of how human cultural and personal values related to scientific practice. She suggested that science was governed by quite real values and normative constraints. Effective study of the methodology of science therefore operated on the basic understanding that scientific practice was influenced by scientists' subjective preferences regarding what ought to be.

Proponents of the inductive theory of science suggest that scientific knowledge is built by induction from the secure basis of observation, so it is therefore reasonable, they suggest, to regard experience as the source of knowledge (Chalmers, 1982). This theory also leads to the belief that scientists, and therefore science, cannot always be totally objective. The method of induction involves framing a general hypowork by generalising from observed cases to all cases of the kind (Quine and Ullian, 1970). The central factor is the expectation that future cases will be like past ones and it cannot be expected that every trait shared by past cases would carry forward to future cases. Quine and Ullian therefore concluded that induction is essentially just a matter of learning what to expect.

The Theory-dependence of Observation

The suggestion advanced by Kuhn that paradigms are incommensurable is largely based upon the idea that all observations are theory-dependent. Observations may be guided by a hypothesis and they may be consequences of the hypothesis together with other assumptions that scientists make. In science, observation normally leads theory, but in extreme cases of well-established theories an observation that conflicts with the theory may be waived. The suggestion has been made, by Quine and Ullian (1970), that science as a whole is a system of hypotheses that accommodate all observations to date, minus such ones as scientists have found it in their conscience to pass over. These authors defined hypotheses as explanations that might be framed to make up the shortage in predicting the future provided by observations, plus self-evident truths.

There are many similarities between optical vision and the understanding of objects produced by humans. Humans learn to behave and to experience as if they were "direct realists". Therefore the learning process associated with objects and knowledge produced by humans is, according to Popper, not natural, but cultural and social. He suggested that learning occurs by practice and active participation rather than by direct vision or contemplation. In this process, published or incorporated theories may also play a role. Part of a scientist's training is "learning how to see" things in a particular way or experience in perception. It is, for example, difficult to perceive the mitochondrion in slides under the microscope before training and experience (Popper, 1977). This eminent scholar concluded that all observations, (and even more, all experiments), are “theory impregnated” since they are interpretations in the light of theories. Popper further wrote that humans observe only what their problems, interests, expectations and action programs make relevant.

The inductivist view of science, that science starts with observation, is, according to Chalmers (1982), undermined by “the theory-dependence of observation” (Chalmers, 1982, p. 34). Chalmers (1982) explained the notion of the theory-dependence of observation when he discussed an experiment in which subjects were asked to draw a card from a pack. On drawing a red ace of spades, which had been printed and inserted in the pack by the researchers, subjects either called it a normal ace of diamonds or a normal ace of spades. In a regular pack of cards it is not possible to draw a red ace of spades, but only a black ace of spades or a red ace of diamonds. However, in this experiment, the personal experience and therefore knowledge and expectations of the observer, incorrectly determined what was seen. He concluded that:

> ..what an observer sees, that is, the visual experience that an observer has when viewing an object, depends in part on his past experience, his knowledge and his expectations. (Chalmers, 1982, p. 25)

The views of Chalmers as to the theory-dependence of observation agree with Popper’s views. Chalmers even suggested that the differences in what a person sees were not due to differences in interpretation, and concluded vehemently that visual experiences were not given uniquely, but varied due to the knowledge and experience of the observer.

It is important to note that Chalmers focused his discussion on occasional scenarios and case studies that may occur, and examples that he referred to as “contrived”. Most of these cases might have only a minor effect on scientific advance. Furthermore, it is true that within the scientific enterprise power struggles develop, and these may affect the course of inquiry, as is true of most academic enterprises.

A Realistic View of Science

There is a need to present a more realistic picture of science than either that of positivism or falsificationism. In addition to Chalmers’ (1976) account of the way in which the theory-dependence of observation may sometimes affect the objectivity of science, his particular view of objectivism is more realistic than the traditional philosophical accounts. However, this view only applies in some instances to the scientific method. Objectivists stress that knowledge has properties that may transcend the beliefs of the individuals who devise and contemplate it. In the analysis of knowledge the first concern of objectivism is with the characteristics of knowledge rather than with the attitudes or beliefs of individuals. While advocates of constructivism and post-structuralism decry this assertion, as Chalmers suggested, it has a place in science.

Chalmers believed that propositions have objective properties that are independent of an individual’s awareness. He explained this belief by citing Maxwell’s lack of awareness of one of the most dramatic consequences of his own electromagnetic theory, which involved the prediction of a new kind of phenomenon, radio waves. In addition, Maxwell’s work undermined the view that the material world might be explained according to Newton’s laws, and this view was strongly supported by Maxwell. This second claim further supports Chalmers’ conclusion that problem situations have an objective existence.

The final consideration in support of Chalmer's claims is that science is a complex social activity in which the results of experimental work are subjected to critical appraisal and scrutiny by other scientists. These scientific colleagues either review the work of other scientists by conducting further testing procedures, or by acting as referees for journals (Chalmers, 1976). Science has an invisible series of checks and balances that ensures, in most cases, that the power structures in science can be relied on to serve the general interests of the scientific community. Some scientific ideas and technological applications also receive public scrutiny through the media and public debate.

Science should not be defined by its negative aspects since it is easily seen from the effective use of science in contemporary societies that, on the whole, science works. Consequently, the positive features of science and the methods that gave rise to them, as well as a realistic appraisal of the limitations of science should characterise STS education. Ziman (1980), discussed this realistic "positive" picture of science, and concluded that STS education should be concerned with what science is and what science knows and does. He wrote that science is a social process that receives communal validation by critical interactions and agreement achieved between scientists.

In addition to the influence of values, or factors affecting both individual scientists and the direction of science, the ideas held by society have a profound effect on the direction that science takes. In modern times, science is regarded as a means of solving social problems. This proposal is not neutral, and impinges on the structure of society itself, and whether certain procedures and priorities benefit or disadvantage particular institutions or individuals.

Implications for Science Education

The preceding outline of the STS view of science highlights the need for secondary science courses to shift from presenting science as an objective body of absolute truth to a more accurate representation of science. Science should be viewed as a way in which humans explain the world around them. As a consequence, science may be influenced by social ideals and values, as well as by the values of individuals. This view has gained a great deal of support in the past 20 years. In 1980, Ziman wrote that science was being taught as a valid field of learning with a true spirit that was objective, broad-minded, critical and creative. He believed that this inadequately prepared students for life in the real world, since it was ill founded and presented scientific knowledge as material to be valued without separate justification.

The Social Construction of Science

As Ziman (1980) has emphasised, valid science cannot be taught as if it were unconnected with the world around it, since there are many ways in which science and society are linked, especially through the technological applications of science. The importance of this interconnection between society and science was upheld by Holton (1978) when he wrote that any product of scientific work was profoundly influenced by the sociological setting in which the science was developed, the cultural context of the time, and the scientific knowledge of the larger community. Science is socially constructed in this way, so it is not possible to teach science in a valid manner without looking at areas of STS education such as the influence of sociological and cultural factors, including politics and religion, upon the progress of science. These controversial issues, and conflicts between their supporters, are extremely important features of the social context of science, and should be included in science courses that aim to prepare students to function as vital participants in a changing world.

In 1985 there was widespread agreement regarding the need for reform in the area of science and technology education provided by schools in the United Kingdom (Royal Society, 1985). It was considered important that all citizens, according to their individual abilities, should possess scientific knowledge and skills of inquiry that would enable them to act in an enlightened way for the benefit of society. Roby (1981) suggested that one of the aims of the STS movement was to bring together scientific knowledge and human wisdom, knowledge and charity, and to instil both compassion and human understanding into the scientist's education. When discussing the benefits of the STS approach to science teaching Bybee (1987) asserted that the STS theme had caused review and clarification of the conception of science education. Bybee suggested that the STS theme should be seen as central to science education.

Lowe (1993) agreed with this view that science education should not focus upon the objectivity of science, when he suggested that science should not be taught as a stable body of eternal truths, but as a sequence of different world views. He strongly emphasised the STS view that observations in science are theory-bound and are thus affected by subjective influences. Science is not socially neutral and values play an important role in the choice or acceptance of paradigms. As Lowe therefore concluded, a science course which included discussion of STS issues would present a much more realistic impression of scientific activities.

The Changing Perceptions of Science Education

Science and technology play an important part in developed countries. Consequently it is important that science education in these countries, of which Australia is one, provides all students with the knowledge and skills that enable the members of Australian society to engage in public debate on the direction of science and technology. These considerations have led to a change in the perceptions of science education. It has been indicated in the previous discussion of the STS issues that secondary science courses should include both consideration of the effects of individual scientists on the direction of science, as well as of the interrelationships between science, technology and society.

This role for science education would be difficult to achieve within a secondary science teaching methodology where, as Conant (1947, p. 16) suggests, "students have to take on faith, statements on scientific laws and the structure of matter which are almost as dogmatic as if they were handed down by a high priest". Conant did not blame the science teachers for this, since he suggested that there was no other way of presenting factual knowledge. This is certainly not the case today in South Australia, if indeed it ever was. In South Australia, the inclusion of STS issues in science curricula (as suggested by the SACE syllabi and the Documents of the National Statements and Profiles (Curriculum Corporation, 1994 a, b) has the potential to contextualise science education and assist students to understand the nature of scientific knowledge. This present study endorses this underlying rationale and seeks to investigate some of its consequences for student learning.

The Need to Revise Science Courses Constantly

The profound social and economic changes that have occurred in recent decades are only an indication of the changes that will occur in the lifetimes of our present secondary school students. The past 30 years have also witnessed significant developments in science and technology that are of vital importance to the community and may also profoundly affect their lives. The interaction between society and these major developments in science and technology present issues upon which citizens need to formulate value judgments. The requirement for citizens to make decisions in relation to these science-based issues therefore highlights the need to teach science in a valid manner. High school science education is the only formal science education that most of the people in Australia receive, so it is important that secondary science should be taught in a relevant manner (Lowe, 1993). Solomon (1992) supported this view and stressed that science education must be a vital ingredient in young peoples' thinking about science-based issues which the members of society have to resolve, such as global environmental problems and the use of new medical technologies.

The discussion in this chapter is based on the assertion that as times change, so too do the purposes of education. This assertion highlights the need to revise science courses constantly. The aims and goals of science education have changed in order to inform secondary science students of the relationships between science, technology and society, as well as equipping them with the basis to make decisions on issues that profoundly affect their lives. Aikenhead (1992) agreed with the need for revision of science courses when he concluded that to provide motivation for students, it is important that science is taught in a way that gives students some relevant, meaningful reference points in terms of their experience and knowledge of the world around them. Science educators who value a student-centred, socially relevant science syllabus therefore promote a science, technology and society (STS) approach.

A central goal of science education is to help students to understand their environment and themselves. Humans aim to use the earth's resources to improve their quality of life and effective science education should encourage them to do this responsibly. Science, technology and society education should be an extremely important part of the curriculum as the resolution of a number of social problems depends, in part, on knowledge and skills in science and technology. In addition, this type of science education offers a sound means of developing skills and insights that have educational value well beyond science itself. Cutcliffe (1990), suggested that the major curricular mission of the inter-disciplinary field of STS education was to present science and technology as enterprises that are shaped by and help to shape human values and, in turn, cultural, political and economic institutions.

Contemporary developed societies are depending increasingly upon science and technology to alleviate social problems or to make life faster, easier and more efficient. There are many value-laden issues concerning technologies that should be addressed for the protection of human rights and the dignity of the individual. Unfortunately, however, in a large number of cases, these technologies have produced unexpected side effects and other serious problems, some of which were not predicted, or else were ignored before the technological fix was introduced.

Consequently, there is a need for clarification of popular thinking about the methods of science, since this would lay the basis for a more effective discussion of the ways in which science and technology might assist in the solution of human problems (Conant, 1947). A more detailed discussion of these issues forms the basis of Chapter 6 in this work. Issues ensuing from the interrelations between science, technology and society are important considerations for all members of society, and are worthy of widespread debate. These issues include the moral implications of technologies such as antenatal diagnosis, genetic engineering and *in vitro* fertilisation, and the influence of particular groups in society upon decisions in regard to energy policy, pollution and other environmental issues.

Secondary science courses need to include discussion of these issues, and thereby prepare students to take their place as vital participants in a changing world. For increased debate on the directions of science policy and public policy, the members of society need to be well informed about the issues in STS, and the nature of science and scientific knowledge.

Science does not hold all of the answers to current social problems. It is important that science courses have been revised to present a realistic picture of science, which includes considerations of science as an evolving view of the world rather than as an objective body of absolute fact. The philosophy and epistemology of science are important considerations for secondary science courses, as discussed in this chapter. This shift in science education to include studies in STS allows students to develop a realistic understanding of the nature of science and technology. Thus, as Ziman (1980) concluded, STS education has become a vehicle by which tolerance of controversy, diverse opinions and unpredictability of the outcome of action may be illustrated to the student.

Summary

In this chapter, the changing view of the philosophy of science and the educational implications of this changed view of science have been discussed. Kuhn argued that normal science proceeds within the boundaries of paradigms, which provide both the rules and definition of the daily problem-solving activities of scientists. Science is an organised social activity, and the decisions of scientists are often value-laden. Feyerabend believed, however, that science had insufficient concern for humanity.

It is important to consider the human face of science in discussions of the nature of science and the nature of scientific knowledge. The characteristics of scientists, including their values, imagination, creativity and personal preferences influence their observations and discoveries. The values and ideals of society also have an effect on the direction of science. Personal and social factors therefore have an influence upon the development of science and technology in societies. Observations in science are also theory-laden. Thus, the objectivity of science is called into question.

The STS view of science acknowledges that since science is value-laden, it cannot always be completely objective. Thus, there has been a worldwide change in science education to include consideration of the issues of STS. Moreover, in modern societies the work of scientists receives considerable scrutiny through peer-review and public examination through the media. Science and technology have significant effects upon the lives of citizens in modern societies. Thus, it is important to present students with a valid image of the nature of science and the nature of the interactions between science, technology and society to enable citizens to take an active role in social debates in relation to decisions involving STS issues. In order to fulfil the purposes of science education in a community that is increasingly dependent upon science and technology, science courses need to be revised constantly. The development of STS courses that present this different model of science is discussed in the next chapter.

3

The Development of STS Courses

In the preceding chapter the changing perception of science that was outlined arose from the work of philosophers of science. One of the first philosophers of science, Francis Bacon, wrote in the early seventeenth century of the ideal of science for the relief of human suffering. Likewise, the STS movement in Australia has its origins in the aim of science and technology for social well-being (Roby, 1981). The notion of social responsibility in science both in the United States and in Britain emerged after the dropping of the first atomic bomb (Solomon, 1988). The dramatic effects of the bomb convinced scientists such as Oppenheimer of the need to accept social responsibility for the results of science and technology. The re-orientation of science teaching towards STS also had the need for social responsibility in science and the need to monitor and assess the interactions between science, technology and society as its underlying motivations, or driving forces.

A Review of Global Research and Change

In this account of the introduction of STS courses, research and change are reviewed by tracing the development of the shift towards STS. The incorporation of STS into science curricula is still a fairly recent phenomenon, and the developments that fuelled this substantial shift in the emphasis of science courses are worthy of consideration. Growing awareness, in recent years, of both the potential social benefits of science and technology, and pollution and other environmental problems have led, in many countries, to dissatisfaction with conceptually dominated science courses. These traditional science courses did not explore the relationships between science, technology and society. Different teaching strategies were required in order to enable effective discussion of the value-laden issues of STS, in the many science courses that shifted towards the inclusion of STS objectives. Although there has been a shift towards the inclusion of STS objectives in a substantial number of secondary science courses in countries such as Australia, the STS movement has encountered difficulties in trying to influence the content of powerful subjects like physics and chemistry (Fensham, 1988b).

The Changing Perceptions of Science Education

In the late 1950s and early 1960s, significant government-sponsored reform of school science education started in Britain and the United States, in response to the growing awareness of the importance of science. These reforms in the curriculum and the updating of course content sought to address the mismatch between the preparation of science students in secondary schools and the needs of university students through the provision of conceptually dominated school science courses. The expanding economies at this time created a strong societal demand for an increased number of scientists and technologists (Fensham, 1988a).

Secondary education became accessible to a much larger proportion of the population during the 1960s. As Fensham (1988a) contended, before the 1960s, upper secondary schooling in most countries was still a phenomenon in which only a few of each age cohort of school students participated. However, Fensham suggested that during the 1960s, secondary schooling began the transition from an elite to mass education (Fensham, 1988a). In the 1960s there was also an emergence, in Western countries such as Britain, of some innovative science education projects such as *Nuffield Science* and *Science 5-13*. In the United States, however, many of the new science courses produced during the 1960s such as *PSSC* and *Chem Study* were conceptually dominated rather than process dominated like *Nuffield Science* and *Science 5-13*. Wallace (1986) argued that these American science courses were concerned exclusively with scientific knowledge and understandings rather than activity, scientific processes and invention, in an elitist movement that aimed to produce more scientists in the prestigious disciplines of physics and chemistry. Solomon (1988) argued that the emphasis in North American science courses in the 1960s was on concepts and further contended that in North America, at the beginning of the shift towards STS, the issues of STS were discussed mainly in social studies classes.

The 1970s saw growing dissatisfaction with the majority of the science courses produced in the 1960s. In these courses the social relevance of science and technology was not discussed, and this was a time when society was becoming increasingly dependent upon technology (Fensham, 1988b). The shortcomings of the science courses produced in the 1960s in many countries resulted from the highly theoretical nature of these courses, which could be addressed by exploring the relationships between science, technology and society. Such a course was considered to be meaningful and appropriate for students not specialising in science at the secondary school level, as well as for those specialising in science (Rosier and Keeves, 1991). It was, therefore, important that the teaching of science in schools should change to include objectives in relation to STS. This shift in emphasis in science courses would enable graduates to take an informed, active part in social debate on the direction of science and technology.

Although most of the conceptually dominated science courses in the 1960s did not stress the social relevance of science, an important American curriculum innovation that focused upon STS was the *History of Science Cases for High School* (Klopfer and Cooley, 1966). This series of twelve booklets was prepared after the publication of *On Understanding Science* (Conant, 1947), and *Science and Common Sense* (Conant, 1951) that, as discussed in Chapter 2, established the importance of showing science as a human activity in relation to both society and technology. The human aspect of science was presented by emphasising the interconnections between science, technology and society. Furthermore, the *Test On Understanding Science* (TOUS) was prepared by Cooley and Klopfer (1961) in an attempt to measure students' understanding of the nature of science.

The resources introduced in the late 1950s and 1960s paved the way for developments of courses in the 1970s such as the Harvard *Project Physics Course* (Holton, Rutherford and Watson, 1970), which was an attempt to increase high school enrolment in physics by appealing to a wider variety of students in the United States. *Project Physics* emphasised the historical development of ideas in physics. This course was of significance for the development of STS courses, in that 'the course stressed the *humanistic* roots and consequences of science' (Lewis, 1991, p. 154). The Harvard *Project Physics* was taken up, at least in part, in New South Wales. Although this innovative program was produced in response to the perceived need to increase the number of high school graduates with an understanding of science, there wasn't a widespread STS emphasis in the new science courses of the 1970s (Ramsey, 1972).

The Incorporation of STS into Science Curricula

In the 1980s greater emphasis was placed on the development of projects that included an STS emphasis. These projects fuelled the shift towards the inclusion of STS objectives in secondary science curricula. An important educational project *Project Synwork* (Welch, 1981) was instigated in the United States as an attempt to address the loss of direction and purpose for curriculum development and change that had originally gained its impetus from curriculum reforms in the 1960s (Keeves, 1992a). In 1978, the STS focus group of *Project Synwork,* who were working on potential goals for science education, recommended that areas such as energy and population control should be included in discussions in science classes (Piel, 1980). This two-year study of science education, which was supported by the National Science Foundation in the United States, was important in the development of STS education, since it was a major research program focusing on the STS model. The aim of the project was to begin to seek answers to the curriculum problems of science educators. *Project Synwork* emphasised the goals of personal needs, societal needs and career awareness, and signalled a definite move away from the traditional courses aimed mainly at academic preparation (Wallace, 1986).

In February 1980, in response to a request from President Carter, the National Science Foundation and the Department of Education prepared a report on the condition of science and engineering education in the United States. The recommendations that resulted from this study included the need for science education to prepare citizens to participate in important social decisions concerning science and technology, and the need for the science curriculum to provide for student experiences with an STS focus (Harms and Yager, 1981). Other recommendations which were of considerable significance for the move towards STS argued the need for: (a) STS issues to be included in all science texts; (b) a cross-disciplinary approach to teaching STS; and (c) pre-service and in-service teacher education programs in STS (McConnell, 1982). The recommendations of this report were consistent with the outcomes and underlying assumptions of STS. The report concluded that:

> The contribution of science and technology to national prosperity and security was seen to depend not only upon the competence and inventiveness of scientists and engineers, but also on the great majority of the population. While these people had no direct involvement in science and technology, they were involved in the democratic decision-making processes, and they reaped the benefits of science and technology. (Keeves, 1992a, p. 35)

In addition to this impetus for major curriculum change towards the inclusion of STS in secondary education in the United States, a recommendation to include STS material in British science courses was made by the Royal Society. A publication by the Royal Society in Britain in 1985 suggested that the aims of formal education in relation to science included those that would encourage students to understand the nature of the interactions between science, technology and society and the contribution the science could make to cultural heritage (Royal Society, 1985).

There were great changes to the secondary education system in the United Kingdom in the 1980s. Comprehensive schools taught students in broader ability classes than had characterised the grammar school and secondary modern school system. This was a period of rapid development of science and technology in secondary education, since there was a perceived need to move away from teaching only the traditional academic science subjects that were studied by the more homogeneous groups in the grammar schools.

The Association for Science Education in the United Kingdom produced resource materials for the *Science and Technology in Society* (SATIS) project and the *Physics Plus* project. Holman (1986) highlighted the need for the inclusion of the consideration of STS issues in science classes to make science meaningful and relevant for students. He suggested in the SATIS Teachers' Guide that science and technology with an STS emphasis should be taught in secondary schools because:

> ..we are all born scientists with an innate curiosity about the things around us and about the world and other living things. Some retain this curiosity all their lives, but others lose it - perhaps because the science they study is too esoteric, too academic or too far removed from their everyday lives and experience. (Holman, 1986, p. 13)

Factors which Contributed to the Move towards STS

As a consequence of the developments presented above, in the late 1970s and 1980s STS emerged as a field of study in the secondary school curriculum. At this time, issues that arose from the interaction between science, technology and society incited an awareness of the need for greater social debate with regard to the use of science and technology in society. The hazards of technologies such as the insecticide DDT became obvious, and questions were asked about whether science and technology caused too many problems. Courses in STS that were designed at this time aimed to educate students about the social impact of science and technology (Cutcliffe, 1990). The *Nuffield Biology Units* developed in the United Kingdom focused on the teaching of environmental issues, health and areas such as chemistry and food. These courses represented great reforms in science education in order to emphasise the social relevance of the concepts discussed in science classes.

In the United States, it was not so much courses in STS, as those in environmental education that led the way (Solomon, 1988). The catalyst for this might have been the dramatic pollution of Lake Erie or the increased awareness of other environmental problems. Unfortunately the study of these issues fell under the heading of social studies rather than science (Solomon, 1988). As a consequence they were commonly debated without a sound basis of knowledge and understanding of the problems, and often in a highly emotional context. Science, Technology and Society became a major movement in the United States when it emerged as one of the five focal points of *Project Synthesis* (Welch, 1981). After this, in 1981-83, when the National Science Teachers' Association (NSTA) initiated its *Search for Excellence in Science Education Program*, STS was included as one of the initial search areas. Further research to allow STS to be included as an important component in the school curriculum was undertaken in 1986 (Yager, 1990b).

In 1989, the year that it became possible to view Halley's comet from the earth, *Project 2061: Science for All Americans* was instigated by the American Association for the Advancement of Science (AAAS) (Mayor, 1991). The name *Project 2061* was derived from the fact that children who were about to start school in that year would live to see the comet again when it would next be in the earth's vicinity in 2061**.** The *Science for All Americans* project had, as one key aspect, STS objectives including the need for all citizens to be scientifically literate and to possess an understanding of the role of technology in society. The basic underlying idea was that a scientifically informed public could more easily take part in and support decision-making that involved technological change (Mayor, 1991). Scientific literacy was considered important since it would create the intellectual and motivational foundation for self-directed lifelong learning (Brooks, 1991).

The World-wide Move Towards STS

During the late 1970s and the 1980s, more than two decades after the pioneering educational reform movements of the 1960s, materials from a whole new generation of science education projects were developed and used. Many of these initiatives represented a much more ambitious and comprehensive program to include social relevance or STS objectives than the initiatives of the 1960s (Brooks, 1991). These reforms in science education that began in the United States and in Britain spread to many other countries in the late 1970s and 1980s. It is significant for this present study that a survey of 34 countries conducted by Fensham provided some evidence of the shift towards STS. After the completion of the study Fensham concluded that:

> all but one country reported some movement to STS at two of the three levels (primary, lower secondary and upper secondary) that were considered. (Fensham, 1988a, p. 348)

This increased emphasis upon the inclusion of STS in school curricula resulted in the formation of a working group on development, implementation and research in STS education. The interesting and significant recommendations made by this group at the Fourth International Symposium on World Trends in Science and Technology Education in 1987 included the need to:

> (a) Strengthen the support network among STS researchers,
>
> (b) Establish a clearinghouse type network to collect ideas, issues, material and methods to be used in STS courses around the world,
>
> (c) ©Promote flexibility in the science curriculum so that STS ideas and issues could be an integral part of the science course,
>
> (d) Train teachers to develop relevant material, and
>
> (e) Ensure that STS will be an integral part of the tertiary education science courses in general, and in the training of science teachers in particular. (Hofstein, 1988, p. 365)

It is important to acknowledge that within the science education community STS science education had achieved a special status by the mid 1980s. In a number of countries, education policy statements had called for an STS approach to science teaching. These policy statements were produced in Great Britain (ASE, 1979), in the United States (NSTA, 1982), and in Canada (SCC, 1984). Subsequently science, technology and society teaching materials have been developed in all parts of the world (Keeves and Aikenhead, 1995).

In more recent times, in the 1990s, there has been a worldwide demand for change in science education, since many nations have sought both to improve their students' future employment prospects in a society permeated by technology and to combat environmental threats. These changes were investigated during a study from 1991-

1995 when 13 member countries of the Organisation for Economic Co-operation and Development (OECD) each selected to finance case-studies of innovations in the rapidly-changing subject areas of science, mathematics and technology (*Education Week*, April 10, 1996, p. 1).

The changes in education were in response to the need to present a different model of science, the STS model, in which the human side of science and social and environmental responsibility were emphasised. The Japanese science curriculum for ages 9 to 15 years was revised to focus on human responsibility, individuality and resourcefulness. In Germany, the revised curricula and materials emphasised the relationship between humanity and the natural world. A Canadian case study focused upon an innovative physics course in which students were involved in shaping the unit on electricity to incorporate social issues. Innovative units developed in the United States included *Chemistry in the Community (Chem Comm)* and *Project 2000*, both of which highlighted social relevance (*Education Week*, April 10, 1996, p. 4).

Curriculum reforms undertaken in China included a chemistry course, *Social and Organic Chemistry,* which was designed to show the links between science, technology and society. Yong (1994) suggested that this course was based upon the concept and belief that:

> ..the progress of all sciences and the development and application of new technology are, by nature, social processes. Education should fully reflect this relationship. (Yong, 1994, p. 509)

This innovative course emphasised the need for education to enhance the quality of the education of all members of the general public rather than only the elite few that were catered for by traditional chemistry courses. The course also assisted students to form their own social values in the process of solving problems (Yong, 1994).

This STS approach to science teaching in the courses discussed above was responsive to both social and individual needs, since it included consideration of the nature of science and the nature of scientific knowledge, and encouraged students to think of the social and moral implications of science and technology. As Worthington (1993) argued, it was crucial that discussions of the social relations of science and technology and the process of producing scientific knowledge were included in science courses, since the questions necessary to identify meaningful courses of action would then be asked.

Implementation of STS Courses

The discussion in this section focuses upon aspects of the implementation of STS courses including (a) goals and objectives of STS courses, and (b) teaching strategies and approaches for courses which include STS objectives. The promotion of scientific literacy is one of the many advantages of science courses that are developed and taught with STS as a central focus. In order to assist the implementation of a curriculum shift towards STS in a manner that enables both teaching and learning in senior secondary science classes to benefit from this approach to science teaching, the structure of STS courses and STS and the constructivist epistemology, are both important topics for consideration.

Goals and Objectives of STS Courses

The increased awareness of the importance of science and technology in modern societies has focused attention upon science policy (Roby, 1981) and has also highlighted the need for careful consideration of the goals of STS education. Cutcliffe

(1990) wrote that the central curricular mission of STS was to present science and technology as enterprises that were shaped by, and tended to shape, human values as well as cultural, political and economic institutions.

Over the past 13 years, sets of goals for STS education have been suggested for curriculum development projects from many countries. Many of these goals relate to the effective preparation of students for their lives in increasingly technological societies. Waks and Prakash (1985) contended, by way of example, that after successfully completing their studies in STS, students should have developed a better understanding of their everyday lives and the ability to participate in the formulation of science policy decisions. Moreover, Bybee (1987) justified the inclusion of such personal and social goals in science courses by discussing the purposes of education. He argued that providing for the needs and continued development of individuals and preparing them to take their place in society were facilitated by science education with an STS orientation.

It is extremely important to provide opportunities for secondary science students to appreciate the interrelationships between science, technology and society in order to prepare them adequately for their lives as citizens in modern societies. Thus, many senior secondary science courses have shifted towards the inclusion of STS goals and objectives. A central goal of STS education has been the depiction of science and technology as complex socially-embedded enterprises in which cultural, political and economic values, as well as technical expertise, shape the directions of research and innovation (Cutcliffe, 1990). In order to achieve this goal, it would be necessary that students should have some understanding of social values, ideals and behaviours. As a consequence, there was a need for teachers to give some time in science courses to the exploration of how the processes and values of science related to processes and values in the community (Thomas, 1987).

It is evident from the above discussion that a full and balanced coverage of STS issues, many of which are quite controversial, also requires change in the cognitive processes taught in schools, as the value judgments involved can not be settled by facts, evidence or experiment alone. The goals of STS are aimed at critical and high-level thinking, high-order cognitive skills and the problem-solving and decision-making capacity of students (Zoller, 1991).

Teaching Strategies and Approaches for STS Education

The goals and objectives specified in STS courses involve significant change from previous science courses. In order to enable students to achieve these objectives it is necessary not only to change or extend the content of the courses but also to incorporate different teaching strategies. A number of teaching strategies and different approaches have been suggested for STS education.

The philosophical approach has merit, since discussion of the nature of science and the scientific enterprise would form a solid basis for the discussion of issues in STS. However, as Ziman (1980) wrote, study of the philosophy of science and its social aspects at a satisfactory level could only be achieved after acquaintance with a number of actual case studies that illustrated the theoretical and practical issues. Ziman concluded that the historical approach would, therefore, be a productive teaching strategy for STS. This approach would also allow important STS themes to be enlarged or illustrated.

Discussion of the sociology of science in senior secondary science classes would also be a way of enabling students to consider the reality of the nature of both the daily activity of scientists, and science in everyday life in modern societies. Furthermore, Kelly, Carlsen and Cunningham (1993) suggested that employing the sociological approach offered insightful perspectives on science generated through empirical studies, thereby complementing the philosophical or historical approach. In their article, the authors examined perspectives of various sociologies of science and their implications for science education. Kelly, Carlsen and Cunningham maintained that the benefits of employing discussions of the sociology of science in science lessons were substantial. The authors concluded that:

> Sociology of science illuminates the messy activities engaged in by scientists in the process of constructing arguments. Sociologists' emphasis on framing events, interpreting data, negotiating conclusions, and reconsidering theories render the construction of scientific knowledge more problematic, ill-structured, and social. (Kelly, Carlsen and Cunningham, 1993, p. 216)

In the discussion of issues in STS it is important that the teacher displays sensitivity to the students' views, and carefully chooses appropriate teaching strategies to deal with each particular issue. A large amount of careful thinking is necessary for both teaching and learning about the real nature of STS issues. Thus in their lesson planning and design of curricula which include STS, teachers and those involved in curriculum design should consider the ways in which young people develop knowledge of social systems. Young people's domain of social cognition includes both concern with harm to self and concern with harm to others, so this should be the starting point for instruction in socio-scientific issues. As Fleming (1986) has written, it is therefore pointless to suggest to students that they hold back their social judgments until they know more. The chances of success of the curriculum shift towards STS would be increased by teaching strategies that provide students with opportunities to discuss and debate their views, beliefs and attitudes in regard to STS as their understanding of STS issues develops in science classes.

Concern that discussions of value-laden STS issues should be conducted effectively in secondary classes led Thelen (1983) to conclude that it was most important that students understood how values and mixes of values affected the conclusions at which scientific decision-makers arrived. She suggested that the development of this understanding of values would be facilitated by providing a science classroom where the rationale for forming alternative solutions, and the part played by individuals' preconceptions could be examined. The students would then be able to learn about the contribution that science could provide towards decision-making in society.

Consideration of the role of values in social decision-making would also give more help to students to enable them to work out where their beliefs and values lay on STS issues, whether they followed from the subject matter or were already held by students at the beginning. Since there would often be no "right" answer they also might need to become familiar with the criteria for testing their claims and deciding between the ones on offer (Poole, 1990). In order to help students understand complex social issues with scientific and technological dimensions, Ramsey, Hungerford and Volk (1990) suggested the use of an issue analysis technique. The authors contended that this technique would allow students to study each issue in depth by organising information into a sound framework that highlighted the anatomy of an issue.

The above discussion demonstrates that the inclusion of the discussion of STS issues in science curricula enables teachers to employ innovative teaching strategies that foster the development of invaluable skills. Rosenthal (1989a) suggested that the types of social questions considered in STS studies should include social issues both external to the scientific community such as energy conservation and pollution, and issues internal to the scientific community, such as the nature of science and scientific knowledge.

The balanced pluralistic approach that discussion of STS issues deserves, also favours the development of skills which were believed, traditionally, to be those developed only within other curriculum areas (Wellington, 1986), and this is a further advantage of the shift towards the inclusion of STS objectives in secondary science courses.

STS Education Beyond the Classroom

Participation in STS discussions should help students to understand the science processes in a manner that would enable them to use this acquired knowledge outside the classroom. Consideration of current and technological issues affecting the lives of humans should foster creativity, allowing students to have a hand in constructing the problem and determining the actions concerning it (Yager, 1990a). Furthermore, excursions, resources and activities outside of the classroom should assist the development of students' appreciation and understanding of STS issues, such as pollution, energy generation and conservation.

Thus, it is important to consider the role played by museums and interactive science centres in the development of high school students' views towards STS. Lucas (1991) discussed the use of museums and interactive science centres to give social meaning to the scientific message. He suggested that scientific displays in museums were presented as finished products with little representation of the progress toward present understanding and with little indication of the human endeavour that produced the science. Lucas therefore believed that although science museums could be used for STS education, the problem was that the displays and artifacts did not often give the social context in which the scientific principles were employed. Gore, Stocklmayer and Rennie (1996) supported Lucas's contention when they argued, in Australia, that research about interactive science centres indicates that in displays in these centres, science concepts, particularly the big ideas of physics, were often portrayed without giving the context in which they were applied. This is unfortunate, since excursions to museums and interactive science centres could be a useful adjunct for the promotion of the outcomes of studies in STS.

Excursions and projects beyond the classroom should assist students to achieve the many positive outcomes of studies in STS. These positive outcomes include: the identification of problems with local interest; active involvement of students through using local resources; awareness of careers other than those in scientific research, medicine, or engineering; and the impression of science as a subject with a focus on the future (Yager, 1990a). As Kings (1990) suggested, STS courses draw on knowledge and skills from a wide range of disciplines and the problem-solving approach develops the capacity to apply knowledge for human purposes. A consequence of this empowering potential of studies in STS should lead to the end of lawyers and economists making decisions about scientific and technological issues of which they were often ignorant. Moreover, the inclusion of studies in STS in secondary science education should lead to more informed debate about the STS issues by members of the public before decisions were made.

The Use of Studies in STS to Promote Scientific Literacy

Another outcome of science education that was stated frequently in the 1980s and 1990s was the development of scientific literacy. There has been growing recognition in present times that scientific literacy was a component of effective citizenship, since the number of STS issues that demand public attention was expected to increase. In order to live as a responsible citizen in modern societies, an adequate standard of scientific literacy should include the ability to make sense of arguments on issues like nuclear power, as well as understanding scientific terms (National Science Board, 1990).

The educational outcome of scientific literacy was focused upon by the National Science Teachers Association (NSTA) of the United States. The NSTA maintained that it was necessary for individuals with a satisfactory standard of scientific literacy to think in a logical manner that incorporated an understanding of the value of science and technology, as well as their limitations (Yager, 1990a). The American *Project 2061* also addressed the issue of scientific literacy. The National Council of the project defined scientific literacy according to several general recommendations, the most important of which was the use of scientific knowledge and ways of thinking about individual and social purposes (Walberg, 1991).

Different suggestions as to what constitutes a sound standard of scientific literacy for members of advanced societies have appeared in the literature. An understanding of the nature of science and the nature of scientific knowledge has been identified regularly (Meichtry, 1993). The scientifically literate person is more likely to accept changes in scientific ideas without becoming disconcerted, since this understanding provides people with the intellectual skills necessary to assess truthfully the evidence for and logic of arguments. This ability to appraise advances in science and technology in a valid manner is important in order to enable individuals to take an active part in contemporary societies that are increasingly dependent upon technology. The development of scientific literacy in students is promoted, therefore, through discussion of the issues of STS in science classes. The goal of science education is no longer just to produce scientists, but to equip individuals for life in a technology-centred world. In response to this educational requirement, scientific literacy has become so important an outcome of science education that Meichtry (1993) has suggested that it was the central goal for reform of science education.

The recommendations for the promotion of scientific literacy have much in common with the STS goals and objectives discussed in this chapter. Consequently, in order for high school courses to promote scientific literacy they should include STS objectives, or at least some consideration of STS issues in their curricula.

The Structure of STS Courses

In order to promote scientific literacy and to provide students with opportunities to meet all of the objectives of their science courses, STS materials with an appropriate structure for incorporation into courses should be chosen. After assessing the various course materials available, Fensham (1990) concluded that of the two ways in which STS has been incorporated into science courses overseas, the “central” approach to teaching STS was preferable to the “add on” approach characteristic of the SATIS materials. The “central” approach uses the links between science and society to make sense of the science content for students.

During the past 20 years, however, a diverse range of materials for use in STS courses has been developed, so it has been necessary to extend the dual classificatory scheme for the structure of STS courses that was advanced by Fensham. As Keeves and Aikenhead (1995) have argued, there are more than just two ways of classifying STS courses. In response to the need for a broader classificatory scheme to incorporate the substantial range of STS materials that have been produced in many countries around the world, these authors have presented a scheme that characterises STS courses into eight categories according to:

1. the proportion and organization of traditional science content compared with STS content; and

2. the emphasis given to traditional versus STS content in the assessment of student performance. (Keeves and Aikenhead, 1995, p. 35)

An addition to this scheme which is particularly useful for secondary science teachers, academics and those involved in curriculum development, is the operational definition of each category by reference to published texts and courses that have been developed in different parts of the world. In this more comprehensive scheme, the SATIS materials, which Fensham classified as an example of the "add on" approach, are from category two, "casual infusion of STS content". In category two "standard school science is taught, together with a short study of STS content attached to the science topic. The STS content does not follow cohesive themes." The emphasis in student assessment is that "Students are assessed mostly on pure science content and superficially on STS content" (Keeves and Aikenhead, 1995, p. 36). A wealth of information for course planning is provided by this scheme for classifying STS courses.

STS and Learning

Students develop ideas, views, beliefs and opinions about the physical world long before they enter science classes, and a premise of this perspective is that meaningful learning takes place when these ideas, as well as new ones, are used by the individual to make sense of the world around them. Within this view of learning, the meanings constructed in learning situations are influenced by an individual's knowledge and belief structures. The development of meaning is a process that involves active participation by the learner (Driver and Oldham, 1986). Tobin (1990) argued that learning is a process in which students make sense of the world around them by reflecting on their experiences in order to construct their understandings, views and attitudes in relation to what they already know.

Rather than seeing students as passive absorbers of knowledge and skills, teachers and those involved in curriculum design need to see students as being actively engaged in developing meaning by building on the ideas and purposes these students bring to the learning situation. In this framework for science teaching and learning, the teacher should provide students with learning experiences that enable them to relate their science understandings to events and phenomena (Driver, 1990). The events and phenomena in the STS approach to science teaching are the issues of STS, since discussion of the issues of STS provides students with examples of the social relevance of the curriculum concepts.

Meaningful learning occurs in science courses with an STS emphasis, since students develop their own meaning of events by active participation, by reflection, and by practice at transferring a scientific idea to an everyday context. In this way, students may incorporate new ideas into their existing common-sense knowledge framework, or replace these ideas with more precise scientific concepts (Aikenhead, 1992). In addition, Robottom (1992) has stressed that a more human and socially sympathetic form of science education was needed in order to demystify science. Robottom reached the conclusion that a reassessment of the relationships between science and society embedded in science courses was necessary.

An argument against this approach to science teaching is that students' incorrect ideas may serve as a foundation for the construction of further knowledge (Baird and White, 1982b). This suggestion should not discourage the use of STS issues in science classes, since when sufficient time is given for the explanation of the basic scientific concepts effectively, incorrect ideas would be replaced with more accurate concepts, as Aikenhead and Fleming (1975) have suggested.

The many positive student-learning outcomes of this approach to science teaching on the basis of the STS philosophy have been upheld consistently in the literature. The belief that this approach to science teaching provided students with a more accurate picture of the nature of science, has been discussed in many published reports. Tobin (1990) refuted objectivism in science and argued that in this approach, the goal of science as presented to students is to "construct viable models to fit with current understandings and experience" (Tobin, 1990, p. 31). Driver (1990) also supported the belief in the benefits of this approach to teaching science from the foundation of STS. She decried teaching approaches in which scientific knowledge was portrayed as "objective, unproblematic and fixed or as discovered through individual empirical enquires" (Driver, 1990, p. 13).

A further argument in favour of providing personal and social relevance in the development of understandings in science classes is provided from the philosophy of science. Pope and Gilbert (1983) have contended that significant learning in science only occurred when the facts had personal relevance to the learner. The authors further contended that the traditional approach to teaching neglected this crucial role of students' personal experience in the development of their understandings. These cogent beliefs agree with work on the philosophy of science advanced by Kuhn (1970a) and Feyerabend (1970), which recognised the role of personal understandings in the development of scientific knowledge (Pope and Gilbert, 1983). An argument advanced by these researchers in regard to the relevance of the personal viewpoints of science students, is of particular significance to this present study. It was argued that although effective teaching relied on the teacher having some understanding of students' views, it appeared that science teachers had paid insufficient attention to the views and personal experiences of the students in their science classes (Pope and Gilbert, 1983).

When combined with adequate instruction in the basic scientific concepts, incorporation of STS issues would also provide motivation for students, by presenting science in a way that would give students some meaningful reference points in terms of their experience and knowledge of the world around them (Yager, 1993). It is important for science educators to make allowance for their students' understanding of both the scientific concepts being covered and their social context. This would lead to effective student-centred education for life, since scientific knowledge would not be received impersonally, but would become part of life in the real world and would be influenced by the values and views of the students.

The development of an awareness of STS ideas by teachers and students in South Australia has served as an objective for curriculum development. Furthermore, it has served as a focal point for the curriculum changes introduced in the curricula of the National Statement and Profiles (Curriculum Corporation, 1994 a, b) and the South Australian Certificate of Education (SACE) (Senior Secondary Assessment Board of South Australia, 1991d; 1992a). However, although some efforts have been made to document community views, little attempt has been made to assess or measure students' and teachers' views on STS in South Australia. At this stage of the curriculum shift towards STS in South Australia, it is extremely important to assess and measure students' and teachers' views on STS. As Zoller et al. (1991) have argued, the simultaneous monitoring of the STS views of both teachers and students is essential since:

> ..the establishment of relevant base-line students' and their teachers' STS position profiles are vital for the development of appropriate on-target responsive STS curriculum materials as well as pre- and in-service STS-oriented teacher training programmes. (Zoller et al., 1991, p. 26)

Before discussing this present study in greater detail, however, it is important to consider research and change in STS education in terms of the factors that have led to this significant shift in the goals of secondary science teaching.

A Review of Australian Research and Change

In Australia, both social change and educational research, as well as the media, have played their part in the re-orientation of science courses towards STS. During the 1980s, the media publicised many of the world's problems, such as the ecological impact of modern technology and the potential effects of genetic engineering. This increased awareness led students to seek the knowledge that would enable them to participate in meaningful debate within a democratic society about these issues raised by scientific developments. In this section, areas of Australian research and change in relation to STS courses are reviewed.

Factors which Contributed to the Move Towards STS

Biology as a subject was introduced into the Australian education system in the 1960s. For the first half of the twentieth century, biological topics were taught in a disconnected manner as botany, zoology and physiology, or as having a subordinate role to chemistry and physics. The science reform movement in the 1960s promoted the development of biology as a field in its own right and a consequence of this redevelopment has been the increased numbers of students enrolled in biology at the upper secondary level in many countries, including Australia (Keeves, 1992a).

Fortunately, a large percentage of school leavers in Australia now have a basic understanding of issues relating to biology (Keeves, 1992a). As a consequence of the more extensive study of science, particularly in the field of biology at the upper secondary school level across Australia, it is to be anticipated that in the future there will be much more involvement of members of the community in science policy issues concerned with ecology and the environment as well as genetic engineering.

Furthermore, in the 1970s and 1980s there was also a dramatic increase in the number of Australian students remaining in schools to continue their education beyond the age of compulsory schooling. For male students at the Year 12 level, the apparent retention rate increased from 28.5 in 1968 to 53.4 in 1988. At the Year 11 level, the retention rate for males increased from 42.8 in 1968 to 72.4 in 1988. A far greater increase in the retention rates for female students was experienced at both year levels. The apparent retention rates at the Year 12 level for females were 21.1 and 61.8 respectively in 1968 and 1988, while at the Year 11 level female rates were 35.5 in 1968 and 78.7 in 1988 (Saha and Keeves, 1990, p. 59). This increase in the number of secondary students, combined with the public discussion in the media have highlighted the need for stimulating and informative science courses in order to provide students with an understanding of how scientific inquiry operates in the modern world. This shift of emphasis in science curricula has the potential to enable members of society to improve the lives of fellow human beings by helping to direct the powerful forces of science in a positive way towards the benefit of life in Australian society.

The increased number of unemployed citizens in Australia has also contributed to the identification of the need for a shift towards the inclusion of STS objectives in science curricula. In recent years, the economic conditions in Australia have led to a decrease in the chances of young people obtaining employment without further education at the post-compulsory level. As a consequence of the greater retention of students at the upper secondary level, it was considered important that science did not become an elite subject which prepared only a few students for their careers as professional scientists, but became a useful and stimulating study in its own right (Fensham, 1990). This could be accomplished by giving more time to STS in the science curriculum, particularly at the upper secondary school level. A curriculum, which was designed previously for the small percentage of the age cohort who would attend university, was completely inappropriate for the large percentage of the age group now completing their upper secondary school education.

This more extensive study of science at the upper secondary school level, was expected to result in greater involvement of Australian citizens in the future in science policy issues affecting their lives. The public could make a valuable contribution by thoughtful participation in policy decisions involving underlying scientific issues, even when experts were uncertain. When looking at automobile safety, for example, experts might focus on technical aspects such as seat belts, air bags and radial tyres, while members of the public involved in discussions might consider the driver (Doble and Richardson, 1992).

STS Courses in Australia

This awareness of the important role of the public in determining the direction of science and technology led to the development of a number of Australian science courses which included STS components. The Australian senior secondary science course *Physical Science and Society* that took account of STS objectives was developed in the late 1970s in Victoria (Fensham, 1988b). Materials from the *Junior Secondary Science Project (JSSP)* and the *Australian Science Education Project* (ASEP), which were developed in the late 1960s and early 1970s, were also used widely (Keeves, 1992b).

Roby (1981) suggested in Australia that science, technology and society could not be placed in separate boxes, since this gave the impression that science and technology were free of cultural, philosophical and ethical considerations. Thus, if discussions of science, technology and society issues were included in the school science curriculum, consideration should be given to the cultural, religious, social, political, ethical and economic dimensions of science and technology.

In 1983, the Science Technology and Society project group based at the Mount Gravatt Campus of the Brisbane College of Advanced Education reported that they wanted the status of Australian school science education improved by teaching the interactions of science, technology and society in schools (Hall, 1983). They wrote that science education in Australia was no longer fun, as students quickly lost their enjoyment in the subject, and what was taught was seen by them as being irrelevant to their interests. This was because the social implications and technological applications of science were generally ignored. The group wanted an attractive and meaningful science education for Australian students, even though the suggestion was made that this would be difficult for teachers trained to teach pure science since, “they must start to deal with real life and its uncertainties” (Hall, 1983, p. 35).

Similar reports into education argued that science courses should use real-world examples to examine the manner in which science interacts with society, Wallace (1986) concluded that there was a need to launch into major curriculum change in Western Australia. Subsequently, the need to include discussion of STS issues in Australian teacher-training courses was emphasised by Hofstein (1988). The author wrote that the main obstacle in the implementation of STS courses was the science teacher, as the training of teachers at the pre-service or the in-service stage had rarely touched on the teaching of STS courses or issues. Support for this contention that it was important to focus on teacher education to engender effective change in education was provided by Tobin (1990), on the basis of his experience as a teacher and lecturer in Western Australia. He believed that curriculum change occurred more readily if teachers were provided with opportunities to make sense of the changes, since “teachers have compelling reasons for implementing the curriculum as they do” (Tobin, 1990, p. 29). Tobin later concluded “of particular import are beliefs that prevent a person from implementing changes she believes ought to be adopted” (Tobin, 1990, p. 34). These reports pointed to the need for careful consideration of Australian teachers’ views, beliefs and attitudes towards STS in order to inform pre-service and in-service teacher education, as well as consideration of students’ views, beliefs and attitudes.

The assessment of student achievement of the STS objectives of Australian science courses has also been considered in articles published in Australian educational journals. Thomas (1987) wrote that the science classroom, in contrast to public examinations, was the appropriate place to assess students’ achievement in understanding STS issues. However, there was a need to maintain a proper balance between content and skills objectives and a need for a properly weighted coverage of the syllabus. Public examinations could also not give credit for the participation in and contribution to classroom activities, and Thomas suggested that this might have been one of the reasons that insufficient emphasis had been placed on the teaching of STS. Activities that allowed effective teaching and assessment of science, technology and society units included role-plays, values clarification, debate, and public involvement in controversial issues, media productions and problem solving.

The Goals and Objectives of STS Courses in Australia

One goal of STS education has been the depiction of science and technology as complex socially-embedded enterprises in which cultural, political and economic values, as well as technical expertise, shape the directions of scientific research and technological innovation (Cutcliffe, 1990).

In South Australia, STS objectives feature both in SACE syllabi for secondary science subjects (SSABSA, 1992a) and the documents produced for the proposed National Science Statement and Profiles (Curriculum Corporation 1994, a, b).

The assessment criteria of the SACE Stage 1 Chemistry Course in 1992 stated that satisfactory achievement of the objectives should enable the students to:

> ..recognise and discuss the influence of science on some aspects of their lives. Examples include scientific developments that have improved their quality of life, applications of chemistry that have resulted in unforeseen problems, and applications of chemistry that involve compromise between human demand and environmental impact. (Senior Secondary Assessment Board of South Australia, 1992b, p. 2)

Satisfactory achievement of each objective of the SACE Stage 1 Biology Course should enable students to:

> ..discuss or present a scientific development in the field of biology which has benefited the human race. Discuss the impact on the environment of some biological application. Investigate a possible career in the field of biology. Present informed and considered views on a matter of public concern. (Senior Secondary Assessment Board of South Australia, 1991c, p. 3)

The objectives in the national science statement for Australian schools (Curriculum Corporation, 1994a) include one that is particularly relevant for studies in STS. This states that students should be able to:

> ..understand and appreciate the evolutionary nature of scientific knowledge and the nature of science as a human endeavour, its history, its relationship with other human endeavours and its contribution to society. (Curriculum Corporation, 1994a, p. 5)

The statements of the National Science Profile materials published in March 1994, were based on many educational outcomes of studies in science, technology and society. Ethics and values were embedded in the STS material through the strands, and students were asked to articulate these at Levels 7 and 8. Level 7 included the study of the philosophy of science through the use of historical examples from the lives of scientists, and Level 8 fostered the students' ability to discuss the broader social and cultural perspectives of science (Curriculum Corporation, 1994b).

The Influence of the Media upon Australian Students' Views on STS

It has been suggested that the Australian students' views on the nature of science were formed largely from information and images from television programs (National Board of Employment, Education and Training, 1994). It was important, therefore, to consider both the quality and validity of this presentation of STS issues and the target audience that might be reached in Australia. A survey of 111 Australian secondary students in 1990 found that the majority of teenagers were unlikely to watch a science and technology program such as "Quantum" or "Beyond 2000". This trend was more pronounced amongst females than males, with only seven per cent of the females in the sample liking such programs. The suggestion was made that this was possibly because girls preferred programs relating to animals, diseases or cures for diseases, while boys liked programs relating to sport, cars, space or weapons. The information gained from the survey led to the conclusion that television was not reinforcing or increasing the interest of females in science and technology (Metcalfe, 1990).

A number of programs such as "Beyond 2000" have dealt effectively with issues such as genetic engineering and AIDS in recent years. These subjects were either within or very similar to the areas which Metcalfe believed were of interest to girls. Consequently, the production and broadcasting of these science and technology programs must cast some doubt upon Metcalfe's conclusion. Moreover, since there was a rather small sample size in Metcalfe's study, the results, which the researcher believed showed that Australian television was not reinforcing the interests of females in science and technology, might not be typical of a wider cross-section of the community.

In a later article, Hadley (1992) did not dismiss Australian television programs as an educational medium for consideration of STS issues, but gave examples of simpler strategies, which might be used by science teachers to help students to appraise critically the images of science conveyed to them in television programs, rather than simply passively consuming the information. In this way, as Hadley suggested, students would be aware of the values and constraints that influenced scientists and television program makers. The media would then be able to make a positive contribution by presenting the social issues that arose from scientific or technological developments.

The Content of STS Courses in Australia

The content of Australian STS courses is an important element of this review of research and change in relation to the development of the shift towards STS. In Australia, a number of innovative curricula in STS have used the advances in reproductive technology as a basis for the discussion of the social implications of science and technology. Attwood (1990) suggested that aspects of reproductive technologies that might be investigated by secondary students in Australian classrooms should include surrogacy and children's rights, sex selection, ova supply and health risks to the embryo in *in-vitro* fertilisation (IVF), and gamete intra-fallopian transfer (GIFT). Classroom approaches for these STS topics include print research to allow students to develop the higher cognitive skills of analysis, synthesis and evaluation. The advantage of this type of unit was that it allowed students to consider the actions of the Australian and State Governments by examining reports in this area produced by governments.

Further Australian reports have discussed the social context, ethics and practical problems required for the satisfactory achievement by students of the STS objectives in science courses. In his article, White (1992) stressed that classroom discussions of STS issues that dealt with the subjects of ageing and dying must include consideration of ethics and social responsibility.

Over the past 20 years, proponents of the STS approach to science teaching, both overseas and within Australia, have argued its benefits strongly in the published literature. By way of example, Malcolm concluded that Victorian science educators had "extended the slogan of the 1970s, Science, Technology and Society (STS) to STSP, where P was for personal development" (1992b, p. 13).

Moreover, Malcolm (1992b) made the significant suggestion that a balanced, integrated curriculum should give similar emphasis to each of the components of Science, Technology, Society and Personal development (STSP), which included:

> (a) ..applications and practical problems (technology), (b) the human and social context of science (society), and (c) individual development (personal development). (Malcolm, 1992b, p. 52)

The discussion in this chapter provides strong support for teaching science from an STS perspective. While the STS approach to science teaching has many benefits for student learning, there have been some difficulties experienced in the shift to include STS objectives in secondary science courses in Australia.

The Debate on the Inclusion of STS in Science Education in Australia

An account of the difficulties experienced by an Australian science subject *Physical Science, Society and Technology is* indicative of the sorts of difficulties that the STS movement has encountered when it has tried to influence the content of powerful subjects like chemistry and physics, since the curriculum organisation of Australian secondary science courses has been controlled by strong social forces (Fensham, 1988b). Consequently, in this present investigation of the inclusion of STS objectives in secondary science courses in South Australia, it is important to acknowledge that there are powerful constraints operating in relation to physics and chemistry and STS.

An educational system that aimed to prepare students effectively for their lives in a world, which was becoming increasingly dependent upon technology, would provide students with opportunities to experience different ways of thinking about future options. Lowe (1993) emphasised this educational imperative, and concluded that it was important that the future approach to science teaching should focus on process as well as content. While it would not be possible to predict with certainty the skills and knowledge that were needed in the future, it would be important to focus on giving students the ability to cope with a world of rapid change.

In the traditional didactic style of teaching, science was presented as a body of facts that was free of values and socially neutral. This was not only uninteresting for students, but also conveyed a false picture of science (Lowe, 1993). It has been argued above that science education which included consideration of the issues of STS presented the picture of science as a human activity which was, therefore, value-laden and not completely objective. This would be a more valid presentation of science than that provided by traditional science courses.

There has, however, been a good deal of controversy surrounding proposed educational changes over the years, and this has also been the case for attempts to have STS included in Australian science curricula. This has certainly been so for the National Statement and Profiles in Australia, (Curriculum Corporation 1994a, b) which included a substantial STS component in the science curriculum.

Some of the further arguments against the inclusion of STS in the Australian science curriculum have centred around the fairly limited amount of time available for the completion of science courses. Davies (1993) suggested that since there was not time to teach everything, science would miss out if the shift towards STS described in the National Statement were to occur. Davies argued that it was important to teach science rather than to teach about science. He concluded that it would not be possible to teach the topic of energy and include quadratic equations and Ohm's law as well as energy policy.

In the public statement on The Draft National Statement and Profile for Science (Australian Academy of Science, 1993) it was maintained that the problem in the draft Profile and Statement was:

> ..a fundamental error in trying to base science education on a contentious sociology of science. This involved downgrading scientific knowledge and skills as ephemeral and replacing the disciplines of science as practiced by scientists with "issues" derived from social and political agendas (such as supposed gender and ethnic bias). (Australian Academy of Science, 1993, p. 1)

Arguments such as this from the Australian Academy of Science refer to Levels 7 and 8 as areas where:

> ..the teaching of science appears to be replaced by discussion of issues of supposed appeal to students, most of which can not be addressed in an informed way by students with about two years of science education behind them. (Australian Academy of Science, 1993, p. 1)

The survey and interviews used in this project would enable an estimation of the strength and coherence of the STS views of students, and might well refute this claim, which was expressed without supportive evidence by eminent scientists.

At the time of publication of the National Statements and Profiles a number of newspaper articles also reported the problems of including discussions of social issues in science courses.

Bragaw (1992) argued that one of the obstacles to the successful implementation of the study of science, technology and society was that it could not find a "respectable home" or school subject within which to fit itself. This was an unsubstantiated argument, because studies in STS are an important component of science curricula as well as being suitable for social science lessons or in an integrated manner across the junior secondary curriculum. The inclusion of discussion of the issues of STS in secondary studies could have a very positive effect on student learning, since knowledge was ultimately not compartmentalised. An argument was advanced by Bragaw (1992) that the "different attitude towards knowledge" promoted by STS programs presented difficulties for teachers, since they found the request to approach their subject from the STS perspective unacceptable. Bragaw claimed that if teachers had not been taught in this manner themselves, they would be quite resistant to change.

Much of this discussion of the argument against the inclusion of STS in Australian science education has been based upon articles from the popular press, because this is largely where the debate has taken place. Many of the articles published in Australian journals prior to this period, however, supported the inclusion of STS in secondary science curricula. A common theme throughout many of the science education articles from 1992-1993 was the need to equip students with tools for decision-making and effective action on issues relating to STS (Malcolm, 1992a; Robottom, 1992; White, 1992; Yager, 1993). As it was argued in these articles, the inclusion of STS certainly would not water down the content of science courses, but could contribute to an effective, innovative school science program that served the social and personal needs of students.

The provision of a school climate or culture for change should be the first task of any education system that advocated change in an STS direction. It would be important to have staff who were enthusiastic about the inclusion of the discussion of the issues of STS in secondary science classes, and appropriate teaching programs and materials should be supplied. As Bragaw (1992) concluded:

> No one system of innovative change works for all. The search is perpetual, and it must be tailored to the school and community. Whatever the change strategy adopted, the key is to promote, develop, and maintain the Leadership capacities of those willing to advance a new view of knowledge that has implications for the survival of the planet. (Bragaw, 1992, p. 10)

A pre-eminent consideration in this discussion was the need for science education to support the personal development of students so that they were able to realise their potential as human beings, with particular emphasis upon students' decision-making and actions (Malcolm 1992b). Malcolm's focus upon students' views was of considerable significance for this present study that used the VOSTS instrument to measure Australian secondary students' views in relation to Science, Technology and Society. As Malcolm has suggested, science education should not simply focus upon the "teachers' agenda", or helping students to understand a particular scientific concept, but on the views held by the student. These views and beliefs were often very strongly held by the student and might be quite resistant to change by simple tuition. The student's personal development would be fostered through the development of strong and coherent views on STS. Robottom (1992) reinforced this conclusion, and further suggested that the STS issues discussed should include the social influences on the outcomes of experiments, rather than presenting experiments as a way in which objective truths may be established.

Summary

In this chapter, research and change associated with the development of STS courses are reviewed. It is argued that the STS approach engenders scientific literacy and personal development through the development of strong and coherent views on STS issues. These new science courses prepare citizens to take an active role in debates and decision-making in relation to the use of science and technology in society. Studies in STS enable students to achieve the life-long educational goal of empowerment to take a place as a vital participant in a society that is increasingly dependent upon technology. The work of authors discussed in this chapter suggests that the inclusion of STS in science curricula builds on students' perceptions of social issues.

Therefore, the inclusion of STS objectives in science curricula provides both a framework for the scientific concepts studied and motivation for effective learning. The Australian media influence citizens' views of STS and have the potential to provide a forum for future public debates on the direction of Australian science and technology. The education system has a major role in the development of future citizens' perceptions of the interrelationships between science, technology and society. Thus, the introduction of STS courses, as outlined in this chapter, is an important consideration for the future of the Australian society.

It is important for science teachers to focus on the personal development of students by carefully considering the STS views brought to the classroom by students, since these views are strongly held and might be resistant to change. Senior secondary science lessons and curricula should be planned in a way which helps students to build on a strong and coherent knowledge of science when constructing further views on the issues of STS. As a consequence there is a need for an investigation of the STS views of senior secondary students. The findings of such an Australian study should provide valuable information to assist teachers and curriculum developers in the furtherance of effective teaching and learning at the time of the shift towards STS in secondary science curricula in South Australia. In the light of this discussion, it is important to consider the theoretical issues raised by this study in greater detail. The theoretical framework for this study, in terms of factors that determine the success of such curriculum shifts, and the nature of views, attitudes, beliefs and values with respect to issues involving science, technology and society are discussed in the next chapter.

4

The Implementation and Outcomes of STS Courses

The rapidly changing perspectives across the Australian school system with respect to the introduction of STS content into upper secondary science courses have arisen from the development of the National Statements and Profiles (Curriculum Corporation, 1994a, b) and more specifically, in South Australia from the development and introduction of the South Australian Certificate of Education (SACE) syllabi (Senior Secondary Assessment Board of South Australia, 1991a, b). The need to include STS in secondary education, which has been a focus in these innovative curricula, has also been a motivating force for this Australian study that involved an investigation and analysis of the nature of such curriculum innovations.

As the shift towards the inclusion of STS objectives in secondary science curricula occurred in the early 1990s, it was timely in the mid 1990s to conduct an evaluation, involving an investigation and analysis of the ways in which STS was introduced into schools in order to provide information for further developments. This was made possible because the textbooks for secondary science included at this time considerable STS material, since the acceptance of STS education moved rapidly during the early 1990s.

Theoretical Framework

In this present investigation it is important to consider the theoretical issues and perspectives underlying the study before progressing further. There are several theoretical and practical issues that need to be addressed.

1. What is the nature of science and its interrelations with society and technology? Why have these understandings changed so substantially in the past 50 years to the extent that they must now be taught in upper secondary schools? What factors have contributed to the changing educational view that acknowledges the importance of STS?
2. What are the factors that determine the success of such shifts in curriculum?

3. What are the goals and objectives of secondary science education at a time of transition to universal secondary education and the introduction of adult recurrent education programs?
4. What is the nature of views, beliefs, attitudes and values?

These theoretical and practical issues had to be examined in detail before developing the program of research to be undertaken in this study. Unless attention was given to these issues, the study faced the danger of becoming diffuse and without a clear focus. Issues one and three are discussed in Chapters 1, 2 and 3. Issues two and four are discussed in this chapter.

The Nature of the Outcomes of STS Courses

In this discussion of the outcomes of STS courses it was important, first, to consider the nature of what could be measured. This study sought to obtain a measure of the achievement of the STS objectives of the senior secondary science curricula in South Australia. These objectives involved the acquisition of views, beliefs, attitudes and values associated with the interrelations between science, technology and society.

Educational Objectives from the Affective Domain

After questioning whether humans ever thought without “feeling”, Bloom, Krathwohl and Masia (1964) stressed that in the design of educational curricula, it was important to take account of the students’ reactions or responses to the content, subject matter, problems or areas of human experience. The authors believed that the human responses, which should be considered, included the expression of views and feelings in relation to a variety of events and the possession of attitudes towards processes. They asserted that teachers did not distinguish between either thinking and feeling, or problem solving and attitudes when educational objectives were written and classified. This suggestion of insufficient consideration by teachers of students’ views, attitudes, feelings and values is disquieting, since the development of personal and social views, attitudes and values results from education in an open society. Thus, it is important for teachers to consider affective objectives carefully in the design and delivery of school curricula. Affective objectives were defined by Bloom and his colleagues as:

> Objectives that emphasise a feeling tone, an emotion, or a degree of acceptance or rejection. Affective objectives vary from simple attention to selected phenomena to complex but internally consistent qualities of character and conscience. We found a large number of such objectives in the literature expressed as interests, attitudes, appreciations, values and emotional sets or biases. (Bloom, Krathwohl and Masia, 1964, p. 7)

The treatment of the affective domain in the taxonomy of educational objectives developed by Bloom, Krathwohl and Masia (1964) begins, at the lower levels, with the category of *Receiving (attending).* This is an important step that is concerned with students’ orientation to learn what the teacher has planned for them. This taxonomy acknowledges the influence of the views students bring to the classroom upon the understandings constructed by these students. Thus, the following significant consideration was advanced:

> Because of previous experience (formal or informal), the student brings to each situation a point of view or set that may facilitate or hinder his recognition of the phenomena to which his teacher is trying to sensitize him. (Bloom, Krathwohl and Masia 1964, p. 176)

The work of Bloom and his colleagues therefore provided strong support for the need for teachers and curriculum designers to consider students' views on issues related to the objectives of their courses. These views would have an influence on students' predispositions to learn and might determine, at least at the semiconscious level, the direction in which the learners directed their attention towards achieving the various objectives of academic courses. Thus this present South Australian study, which measured students' views in relation to the issues of STS, might serve to facilitate student learning of the STS objectives in the secondary science curricula by guiding curriculum development in a way that built upon the views already held by students.

The taxonomy of the affective domain (Bloom, Krathwohl and Masia, 1964) moves from the category of *Receiving* to the categories of *Responding* and then to *Valuing.* Teachers commonly use the term 'valuing' when writing educational objectives. Valuing something implies that it has worth. Bloom, Krathwohl and Masia (1964) believed that the concept of worth was a social product that students slowly internalized and came to accept as the standard by which to construct their own beliefs and values. Thus consideration of the nature of beliefs and values was significant for this present study, which sought to investigate the relationship between social factors and students' STS views, beliefs, attitudes and values. These social factors, which might influence students' views, beliefs, attitudes and values and thus their learning of objectives in the affective domain, include: (a) social class, (b) school type and (c) school location. It is also important to consider whether views, beliefs, attitudes and values towards STS are related to gender.

Views, beliefs and attitudes characterise a student's behaviour. Moreover, a learner is perceived as holding a value once he or she has displayed this behaviour consistently in appropriate situations (Bloom, Krathwohl and Masia, 1964). Schwartz (1992) suggested that traditional theorists defined values as "the criteria people use to select and justify actions and to evaluate people and events" (Schwartz, 1992, p. 1). He continued to discuss the way in which values influenced attitudes, and reached the significant conclusion that the values of human beings affect the ways they organise their understandings of the world. On the basis of consideration of the writing of Bloom, Krathwohl and Masia (1964) and Schwartz (1992), it would appear reasonable to conclude that the scales developed during this study would measure values in addition to views, beliefs and attitudes. But would this really be the case? In order to answer this question, it would be important to consider, in greater detail, the nature of views, beliefs, attitudes and values.

The Nature of Views, Beliefs, Attitudes and Values

Oppenheim has argued that attitudes have intensity, since they might be held with greater or lesser emphasis or fervency. The problem of insufficient attention by researchers to what was being measured in the design of attitude scales was discussed by Oppenheim (1992). After raising this concern, the author considered the nature of attitude statements and wrote that:

> ..an attitude statement is a single sentence that expresses a point of view, a belief, a preference, a judgment, an emotional feeling, a position for or against something. (Oppenheim, 1992, p. 174)

At this stage of the discussion of what was measured in this Australian study, a further development of the concept of attitudes and beliefs, and comparison with the concept of values is pertinent. The definition of attitude given by Rokeach (1973) is a useful basis for a discussion of the differences between the concepts of attitudes and values.

Rokeach wrote that:

> ..an attitude is a relatively enduring organisation of interrelated beliefs that describe, evaluate and advocate action with respect to an object or situation, with each belief having cognitive, affective and behavioural components. Each of these beliefs is a predisposition that, when suitably activated, results in some preferential response toward the attitude object or situation, or toward others who take a position with respect to the attitude object or situation, or toward the maintenance or preservation of the attitude itself. (Rokeach, 1973, p. 131)

Thus, the beliefs held by individuals precede the formation of attitudes by these individuals. An attitude can be conceptualised as an integration of positive and negative motive forces (incentives) relating to components of the action and its possible consequences (Feather, 1985).

Thurstone provided a cogent depiction of the nature of attitudes when he wrote that the concept attitude indicated a person's "inclinations and feelings, prejudice or bias, preconceived notions, ideas, fears, threats and convictions about any specified topic" (Thurstone, 1959, p. 216). He suggested that opinions were verbal expressions of attitude. In this present study, opinions were an expression of respondents' attitudes in terms of choices of responses to a particular statement on the issues of STS.

A belief has been defined as "something that people believe and accept as true" (Rubba and Harkness, 1993, p. 409). Beliefs typically rest on other underlying beliefs. Some of these supporting beliefs may be founded upon observation, but often in making a belief acceptable to someone there is no need to cite observations. The person may already share enough of another person's supporting beliefs so that they are convinced merely by calling attention to some of the relevant connections. A further definition of a belief as "that which is believed; accepted opinion, conviction of the truth or reality of a thing based on grounds insufficient to afford knowledge" (The Macquarie Dictionary, 1987, p. 191) leaves little doubt that values are at a deeper level of the personality than beliefs. Teachers convince students of certain beliefs by appealing to the beliefs already held by the students and combining these to inculcate the final desired belief (Quine and Ullian, 1970, p. 47).

Values are more enduring, and of greater consequence than beliefs, although understanding of the issues of STS may be affiliated with individual values. The nature of science and STS issues were viewed by Herron (1977) as being allied with a values system. Thus consideration, in greater detail, of the nature of values is pertinent. Values are principles or accepted standards of a person or group (Sykes, 1976). Two potential value bases of interest are, for example, valuing academic independence or valuing community responsibility. From these two value bases, very different individual modes of conduct ensue.

Rokeach argued that there is a close relationship between values and modes of conduct when he wrote that:

> A value is an enduring belief that a specific mode of conduct or end-state of existence is personally or socially preferable to an opposite or converse mode of conduct or end-state of existence. (Rokeach, 1973, p. 5)

Moreover, when discussing the nature of human values and value systems, Rokeach suggested that values were the results of sociological as well as psychological forces. Individuals within society were encouraged to support ideas for the common good, and individual motivations required justification in socially desirable terms.

The term 'value' may refer to standards or principles of worth which make something have value, and therefore guide decisions on whether such things are really worth having or pursuing (Kaplan, 1964). Rescher (1969) wrote that if people subscribed to a particular value they could be expected to take that value into proper account in the process of deliberation and decision-making.

Science has its own set of values that guide scientists when they decide between competing theories or experimental methodologies, and ethical, ideological, and cultural values affect scientific and technological enterprises. Individual scientists also have their own set of values, which contribute to the value-laden nature of the scientific enterprise. As Aikenhead (1985) has suggested, science is value-laden, since contextual values seep into a scientist's set of constitutive values, particularly in cases where the scientific and technical knowledge tends to be vague and inconclusive.

Consideration of the nature of views, beliefs and attitudes thus indicates that it is possible to progress through a continuum from the more superficial attributes, views and beliefs, through to attitudes, and then through to the deeper level of values, and value systems within the person. Thus, attitudes do not exist in isolation within individuals, but have links with the deeper level of values (Oppenheim, 1992). Oppenheim (1992, p. 177) advanced a 'tree model' where opinions were at the outermost shoots of the tree, attitudes were at the branches further towards the trunk of the tree, and values were at the branches located closest to the trunk. The trunk of the tree was the personality of the individual. Values have a deeper level of internalisation than attitudes, which are more focused and more specific. Thus, a secondary school student may have a value of the importance of science in society and this leads the student to have a favourable attitude towards science programs on television.

Rokeach (1973) wrote that values had a motivational component as well as the cognitive, affective and behavioural components, and values were precursors of both attitudes and behaviour. Rokeach suggested that values were standards for influencing attitudes, such as a student's attitude towards the study of science. This Australian study focused on values in everyday-life situations involving choices and decision-making relating to the interactions between science, technology and society which citizens were required to make regularly in modern societies. It was considered in this study that Oppenheim's conception of the level of values on the 'tree model' of beliefs, attitudes and values indicated that the scales used in this Australian study measured views, beliefs and attitudes. However, it did not directly measure values, which are at a much deeper level, and hence more difficult to measure in a valid way. Furthermore, the results of any survey of views, attitudes and beliefs would be affected by the educational standard or level or understandings of the respondents, since the belief and value systems of students with a lower standard of education would be less well-defined and value types might therefore not be as distinct in less educated groups (Schwartz, 1992).

The Role of Education in Developing Views, Beliefs and Attitudes

The reasons why educators and curriculum developers should be concerned with students' beliefs and attitudes were discussed by Hamm (1989). Parents and society at large consider it important that new members of society behave as good citizens displaying inter-personal, social morality. As Hamm suggested, if students were to receive moral education, then they needed to acquire an awareness and acceptance of the rules and principles to employ when making moral decisions. Attempts to change attitudes through processes, which include education, demonstrate the strength and omnipresence of attitudes. The difficulty in changing attitudes provides further support for the need to measure students' attitudes at the beginning of a curriculum change to include STS objectives that are associated with the affective domain.

Attitudes attract strong feelings (the affective component) and are reinforced by beliefs (the cognitive component) (Oppenheim, 1992).

Major curriculum statements of goals and objectives have consistently stressed the importance of the development of scientific attitudes, but insufficient emphasis has been placed on this aim in the classroom (Gauld, 1982). Since Gauld believed that an understanding of the philosophy of science was a fundamental component of the development of scientific attitudes, he abhorred the fact that classroom practice had taken so little account of developments in the philosophies of science. Thus it would seem important for science educators to be concerned with attitudes, beliefs and values involving the nature of science. Topics, of a value-laden nature, encountered in science education include: (a) the ethics of the use of human subjects in research, (b) energy generation, (c) human sexuality, and (d) the termination and inception of life (Poole, 1990). There is not a high degree of consensus among practising scientists in regard to all scientific beliefs and values. Thus, throughout its history of about 100 years, science education has not taken sufficient account of the difficulties in regard to the values involved with the application of science and technology in society.

Attitudes affect individuals' learning by influencing what they are prepared to learn. Bloom wrote that:

> ..individuals vary in what they are emotionally prepared to learn as expressed in their interests, attitudes and self-views. Where students enter a task with enthusiasm and evident interest, the learning should be much easier, and all things being equal they should learn it more rapidly and to a higher level of attainment or achievement than will students who enter the learning task with lack of enthusiasm and evident disinterest. (Bloom, 1976, p. 74)

The attitudes of teachers and students would, therefore, affect the chances of a successful implementation of a major curriculum shift towards STS, since the predisposition of individuals from both of these groups to learn about the issues of STS would depend upon their views on STS.

These distinctions between attitudes, beliefs, values and views are of some importance. However, in this study, while it is recognised that distinctions exist between views, attitudes and beliefs, instead of using these three terms, these different characteristics of individuals are referred to collectively as views.

Issues in the Implementation of a Curriculum Reform

In this investigation of a shift in objectives of secondary science curricula towards STS it is important to discuss the factors that influence the success of such curriculum shifts. Another significant issue for consideration is how such a curriculum change occurs.

Factors that Determine the Success of Curriculum Innovations

Fullan and Stiegelbauer (1991) have suggested that there are nine critical factors that interact to influence the success or failure of an educational change. These factors include characteristics of the change such as need, clarity, complexity and practicality. A major change, which teachers consider to be complex, prescriptive and impractical, is likely to be difficult to implement. Teachers should see the need for a proposed change, and both the personal and social benefits should be favourable at some point relatively early in implementation. The innovations should be translatable into practice with the resources at the disposal of teachers. Moreover, the proposed curriculum should be clearly examined with regard to difficulty, skill required, and extent of alterations in views, teaching strategies and use of materials required for it to be introduced successfully. Analysis of these factors at the early stages of the introduction of a curriculum shift would enable teachers to assess students' performance and evaluate the changed curriculum.

Educational change depends on what teachers do and think. Consequently, if the change were to take place successfully, it would require that the problems faced by busy teachers were better understood by others including administrators, parents and students. For most teachers, daily demands leave little time for serious and sustained in-service education. It has been argued that this unfortunate situation is exacerbated by the fact that teacher training did not equip teachers for the realities of the classroom and the introduction of abrupt change (Fullan and Stiegelbauer, 1991). An investigation of the adequacy of Australian teachers' training to enable them to teach the interrelations between science, technology and society effectively to their senior secondary students should aim to provide information for those involved in the provision of both undergraduate and in-service education of teachers. Teachers' assessment of the shift in the curriculum towards STS in this study would also be an important area for investigation. The criteria that teachers used in assessing a particular change given by Fullan and Stiegelbauer (1991) include:

- Does the change have the potential to address a need? Will students be interested? Will they learn? Is there evidence that the change works, ie., that it produces claimed results?
- How clear is the change in terms of what the teacher will have to do?
- How will it affect the teacher personally in terms of time, energy, new skills, sense of excitement and competence, and interference with existing priorities?
- How rewarding will the experience be in terms of interaction with peers and others? (Fullan and Stiegelbauer, 1991, pp. 127-128)

Assessment of student performance and the evaluation of changed curricula are extremely important, since the successful implementation of a curriculum innovation requires changes in views in relation to that particular innovation as well as changes in teaching practices and teaching styles. Professional development and in-service education in support of specific innovations are also vital for the successful implementation of the changed curriculum. Implementation occurs more readily in schools that foster a learning orientation among their staff. Research into teachers' views of curriculum change is necessary to guide the development of effective professional development for teachers, and thereby enable school reforms to be beneficial (Fullan, 1992).

At this stage of the discussion it is important to ask how would science teachers, who were traditionally trained and skilled in the linear, deductive model (Parker, 1992) assist students to deal with value-laden STS issues? In order to deal adequately with discussions of value-laden STS issues in science classes, students must also receive some education involving attitudes and values, and the way in which to deal with such potentially volatile issues. If a curriculum change included a strong emphasis upon STS, then some secondary teachers might experience difficulty in enabling their students to meet the STS objectives. This could be because some teachers might not have strong and coherent views in regard to the nature of science and the interactions of science, technology and society.

After the introduction of an earlier Australian curriculum change, the Australian Science Education Project (ASEP), the research indicated that student achievement of the course aims in classrooms was generally related to the congruence between the teacher's views concerning science teaching and those embodied in ASEP (Fraser, 1978). The close interrelationship between teachers' views and those of their students was stressed by Lederman (1986) in the United States, in his discussion of students' and teachers' understanding of the nature of science. He supported the need for this present study when he argued that:

> ..since the *sine qua non* of instruction prescribes that teachers can only teach what they understand, it follows that any attempt at defining "adequacy" for teachers' conceptions must involve two criteria. First, the actual beliefs of teachers must be evaluated. Secondly, the *sine qua non* of instruction should lead one to compare teachers' conceptions with those of their students. (Lederman, 1986, p. 97)

Possession of a sound basic understanding of the curriculum material as a significant factor in teachers' feelings of competence was reinforced by a study in the United Kingdom which reported that when teachers felt that they were competent, the chances of the successful implementation of a curriculum were increased (Carre and Carter, 1990).

Unfortunately, many teachers in the United Kingdom did not discuss controversial STS issues in their science classes, as they feared that the substance and cogency of the science they taught might be affected (Ziman, 1980). Furthermore, perhaps, as Thomas (1987) suggested, Australian teachers who had been trained to teach pure science also found it difficult to teach STS, since their crutch of absolute certainty was removed

The success of a curriculum innovation depends upon the reactions of the students and the views of the students towards the new curriculum. These are likely to be influenced by the views of the teachers. Curriculum innovations, which require participation by students in new activities, are likely to be more successful if students clearly understand the activities, and are motivated to try what is expected of them. Many potentially valuable innovations, which involve personal and social development goals, require some changes in student thinking in the classroom. Consequently, as Fullan (1982) has suggested, those responsible for a curriculum change would be well advised to consider explicitly how students' reactions might be assessed both at the introduction of the innovations and periodically throughout implementation. Fullan and Stiegelbauer further supported the need to consider students' reactions and views on curricular changes when they wrote that:

> ..effective educational change and effective education overlap in significant ways. Involving students in a consideration of meaning and purpose of specific changes directly addresses the knowledge, skills and behaviors necessary for all students to become engaged in their own learning. (Fullan and Stiegelbauer, 1982, p. 191)

The study, which is discussed in this book, incorporates measurement of the views in relation to STS of teachers and students as well as scientists, and enables a comparison of these views in the early days of curriculum change. An investigation of teachers' basic views of science would also be important at this stage, since these views would be closely related to both instruction and learning. There must be expected to be a strong relationship between teachers' views and their understanding of how the content should be framed for instruction (Shulman, 1987). However, an investigation of teachers' approach to science and science education was beyond the scope of this study.

In a previous study (Rennie and Punch, 1991), which involved the scaling of attitudes, like this present study, the authors decried the state of attitude research in many former studies. Rennie and Punch contended that one problem in this previous research was that the size of the effects of attitude on achievement was distorted by grouping similar scales together. The second problem was that there was no theoretical framework to direct the development of appropriate scales. In this chapter, the theoretical framework has been considered carefully in order to inform both the development of appropriate scales and questions that would guide effective interviews with teachers to determine their views on the curriculum shift towards STS.

The Nature and Purpose of this Australian Study

An adequate discussion of the nature and purpose of this Australian study requires the presentation of the specific questions addressed in this investigation of the shift towards STS in Australian secondary science curricula.

Specific Questions Addressed in this Study

The critical and initial question addressed in this study is what are the views held by students and teachers in relation to STS issues? Students construct their views towards STS by building on the views, which they bring to the classroom, so a valid measurement of students' views on STS would be expected to assess the outcomes of an effective curriculum shift towards STS. In this way the teachers' and students' views towards STS would reflect the successful implementation of a science curriculum with an STS orientation, and as a consequence were also considered in this study.

The following specific questions were addressed.

- Do students as a group have strong and coherent views on STS? What is the strength and the coherence of students' views in relation to STS?
- Do student-level variables relating to the study of science at secondary school including: (a) perceived academic performance in science, and (b) liking of science, affect the strength and coherence of students' views towards STS?
- Do students in different areas of science differ in their views in relation to STS? How do the strength and the coherence of the views on STS of students in the publicly examined Physics, Chemistry and Biology (PES) subjects and School Assessed Science (SAS) subjects compare?
- Do students' expectations of future participation in science that include:
- expected years of further education, (b) expected inclusion of science subjects in further education, (c) expected science and non-science courses for further education, and (d) expected future occupations, influence the strength and coherence of students' views on STS?
- What is the effect of variables related to home background of students, including mother's and father's occupations, on the strength and coherence of students' views towards STS?
- Are there relationships between school-level variables that include: (a) sex of school (co-educational, single-sex boys and single-sex girls), (b) type or governing body of school (government, independent or Catholic), (c) school location (metropolitan and non-metropolitan), and (d) socioeconomic status of school (average socioeconomic status of father's occupation) and the strength and coherence of students' views towards STS, students' liking of science, and students' expectations of further study of science after the completion of secondary school?

- Do interactions between multi-level variables influence (a) the strength and coherence of students' views on STS, (b) students' liking of science, or (c) students' expectations of further study, particularly of science?
- Is there a relationship between the sex of students and the strength and coherence of students' views towards STS? Do males and females differ in their views towards STS?
- What are teachers' views in relation to the recent shift in the emphasis of the South Australian secondary science curricula towards STS? How do the teachers translate the STS curriculum into what happens in the classroom? What are the gaps in their views and what are the implications of this for the training of teachers?
- Do teachers have strong and coherent views in relation to STS? What are the differences in the strength and coherence of the views towards STS of secondary science teachers and their students at the upper secondary school level?
- Do scientists have strong and coherent views in relation to STS? How do the strength and the coherence of teachers' views on STS compare with the strength and the coherence of scientists' views on STS?

Variables Used in the Analyses

This investigation of the shift towards STS in South Australian secondary science curricula employed scales and structured interviews. A detailed account of the methods employed and the results obtained in this investigation are discussed in the following chapters.

After a review of previous research and discussions with teachers and students, it was considered that there were a number of variables that might affect students' and teachers' views towards STS. Consequently, data relating to these variables were collected during the study. Furthermore, from consideration of previous research studies related to achievement outcomes, in particular the study reported by Keeves (1992) it was decided that the clusters of variables used for the analyses in this study should include:

- expectations of future participation in science by students, including students' expected science courses and occupations;
- participation in science at the secondary school level;
- home background (a measure of the factors influencing the cultural and status characteristics of the students' homes); and
- social and economic context and location of the schools.

The Need to Examine Views on STS

Discussion of the aims of previous studies further demonstrated the need to examine views on STS. There have been no previous Australian studies that have measured views on STS. Nevertheless, several previous overseas studies have investigated students' views towards STS, and one of these studies used scaled *Views on Science, Technology and Society* (VOSTS) items at a similar time to the scaling of the VOSTS items in this Australian study. Hence, consideration of previous studies of views on STS further clarified the purposes of this present Australian study.

A Canadian study of high school graduates' views about science, technology and society demonstrated that the majority of students held the view that science served the public interest and that quality of life issues should be the basis for research funding. Fleming summarised the students' views of the interaction between science and society, in a clear way when he suggested that:

> Science (technoscience) should inform society in order to resolve socioscientific issues, issues that students perceived as technical problems; but society should inform science in terms of science policy as it guides research programs. The formulation of policy for a research program was not perceived as a socioscientific issue. (Fleming, 1987, p. 185)

Another Canadian study (Zoller and Donn, 1991) used four VOSTS items to examine both the beliefs of Grade 11 students enrolled in an STS course and those who were not. The results of this study indicated that a substantial change in the STS beliefs and positions profile of senior high school students occurred as a result of their being exposed to an STS course. The author advanced the suggestion, which supports the purposes of the present study, that an assessment of both students' and teachers' STS views was a necessary condition for the design and implementation of appropriate STS courses, and for an evaluation of the course's effectiveness in delivering curriculum changes. Zoller and Donne were appropriately concerned that any change in students' views should occur through education rather than indoctrination.

Furthermore, a later study on STS education conducted in Iowa (Yager, 1993) revealed some great successes with STS programs. The work compared the outcomes of classes taught using textbooks featuring STS strategies and classes taught from the regular textbooks. It is significant for this study that the views of students in STS classes were significantly more positive than the views of students not in STS classes. These students also displayed the characteristics of the scientifically literate person, such as the ability to weigh the possible consequences of alternate actions and engage in responsible decision-making.

A previous study by Rubba and Harkness (1993), involved an empirically developed instrument to examine pre-service and in-service secondary science teachers' STS beliefs. The authors began their article with the assertion that in light of the increased STS emphasis in secondary science curricula, it was important to investigate the adequacy of teachers' understandings of the issues of STS. The authors proceeded with the suggestion that it was important for teachers to have adequate conceptions of STS, since science teachers were held accountable for the adequacy of student conceptions of the nature of science. In their conclusion, they claimed that:

> ..the results showed that large percentages of the in-service and pre-service teachers in the samples held misconceptions about the nature of science and technology and their interactions within society. (Rubba and Harkness, 1993, p. 425)

After Rubba and Harkness's (1993) findings of misconceptions in teachers' beliefs on STS, they recommended that these teachers study STS courses, since the college science courses that had been studied by these teachers did not appear to have developed accurate conceptions of STS issues in these teachers. It was, Rubba and Harkness suggested, important for teachers to have strong and coherent views in relation to the issues of STS.

Like this present study, in a 1996 study, Rubba, Bradford and Harkness (1996) scaled a sample of VOSTS items to measure views on STS. Rubba, Bradford and Harkness asserted that it was incorrect to label item statements as right or wrong, and proceeded to charge a panel of judges to classify the responses so that a numerical scale value was allocated to each of the responses. This scaling was used to determine the adequacy of teachers' views on STS as assessed by a scale that gave partial credit to particular views, and greater or lesser credit to others.

The discussions in this chapter and the preceding three chapters have shown why at this point of time the accurate measurement of views towards STS was extremely important. The results could provide important information to teachers and curriculum developers, thus guiding curriculum development in relation to STS, as well as informing administrators about the progress and significant issues relating to the shift towards the inclusion of STS objectives in senior secondary science courses in South Australia.

Summary

The theoretical perspectives for this Australian study include consideration of the nature of (a) science, (b) the interrelations between science, technology and society, (c) affective domain objectives, and (d) the issues of curriculum change. In addition, theoretical perspectives involve the identification of outcomes which relate to the affective domain that could be measured in this study.

The views, which students bring to the learning situation, influence the understandings, attitudes and values that are developed by these students. Students respond to their school curricula by valuing or judging the worth of issues in classroom discussions. Values are, however, at a deeper level of the personality of individuals, and are thus more difficult to measure directly than views, beliefs, and attitudes. Nevertheless, values provide the foundation for the formulation of views, beliefs and attitudes. Thus it was considered important in this study to measure students' views, including their beliefs and attitudes, in relation to STS, but the complexity of underlying values led to their being omitted from consideration in this study. Likewise, the study did not seek to assess students' knowledge and understandings either of science or STS issues, since it was argued that such understandings were driven by scholarly knowledge, while the study sought to assess students' views expressed in their own terms.

In this chapter, the theoretical perspectives of the present study have been presented, and certain features of the design and methods of this study, which enable the study methods to contribute significantly to knowledge in the area, have been discussed briefly. In the next chapter, the methods used in this study are considered in order to show both the unique features of the study and its original contribution to knowledge in the area.

5

Research Methods and Materials

In this investigation of the shift towards STS of the South Australian senior secondary science curricula, the views towards STS of students, teachers and scientists were measured. The overall aim, which guided this study, was to construct a “master scale for STS”. It was necessary to develop and test scales to measure and compare views towards STS. Systematic methods of data collection and analysis were necessary. This method of data collection using scales also required careful consideration of the issues of strength and consistency. In order to address the research items in a valid manner, it was important to first establish the strength and consistency of students’ views using Rasch scaling. The validity of the scales used in this present study was confirmed on the basis of a review of the literature on the philosophy of science and the issues of STS (see Chapter 6), as well as by using the viewpoints of the experts (see Chapter 7).

In addition to the use of scales to gather data, group interviews and discussions enabled the collection of information on teachers’ opinions and concerns in relation to this shift in the objectives of secondary science curricula in South Australia. The study was conducted in South Australia during the early stages of a shift towards STS in the objectives of senior secondary science courses, and the teachers in the state were experiencing considerable pressures due to increased work loads and time demands. Consequently, the development of a master scale to measure views on STS required a sequence of carefully considered research methods and materials. The methods and materials used in this Australian study are discussed in this chapter.

Planning the Study

Before collecting the data for the study, the completion of a number of tasks was necessary in order to increase the chances of the study proceeding effectively. The required tasks are discussed in this section.

Fieldwork and Literature Review to Identify the Issues for Investigation

From October to December 1992, a 10-week visit to the United Kingdom and UNESCO Offices in Paris on a United Kingdom/Australia fellowship for teachers of science provided a valuable opportunity for the discussion of STS education with secondary teachers, university academics and others who were actively involved in educational research and development in the area of STS. The discussion, during the visit to UNESCO Headquarters, of science curricula with an STS-emphasis that were used in a variety of developed and underdeveloped countries around the world, proved invaluable for framing the context and theoretical foundations of this present study. In the British National Curriculum, consideration of the issues of STS featured as the foundation of many science courses, so familiarity with the British teachers' views and attitudes to education in STS provided a broader understanding of the issues involved. Presentation of seminars and workshops to British undergraduate student teachers and practising teachers, who were studying for postgraduate qualifications in education, also facilitated a valuable exchange of ideas in relation to STS education. Discussions focused around six topics relating to education in STS were held with teachers during visits to a wide range of schools in Southampton, The Isle of Wight, Cambridge and Sheffield.

In July 1993 a workshop was presented at the Conference of the National Science Teachers' Association (CONASTA 42), and this enabled a greater understanding of Australian science teachers' views, attitudes and values in relation to education in STS to be obtained. Moreover, by living on site at the conference venue for a week with fellow conference participants, many opportunities were afforded for discussing the issues of STS education with a variety of Australian science teachers. A seminar presented at the Orphanage in Adelaide at the South Australia Science Teachers' Association's Spring Workshop Series also enabled further investigation of South Australian teachers' opinions of teaching and learning in relation to STS. On each of these occasions within Australia and overseas, the six questions, which also formed the basis of the teacher interviews in this present study, as discussed in Chapter 12, were asked of teachers in group and individual situations.

This exchange of understandings, ideas and curriculum materials was an extremely important component of the study, as it presented an opportunity to develop a first-hand acquaintance with the issues and developments in STS education in the United Kingdom, as well as a clear understanding of the British teachers' views, attitudes and understandings in relation to education in STS. The visit to the United Kingdom and France in 1992 thus provided a firm foundation for subsequent discussions with Australian teachers about STS education in 1993. Moreover, it set the scene for the ensuing field work, since areas that needed to be addressed and items that needed to be answered in relation to this major South Australian curriculum change towards STS were identified. This shift in emphasis of curricula was a feature of the South Australian Certificate of Education (SACE) Chemistry (PES) and Biology (PES) syllabi instigated in 1991 (SSABSA, 1991a,b), and the National Statements and Profiles that were introduced in 1994 (Curriculum Corporation, 1994a, b).

As well as this exploratory fieldwork during the early days of the study the literature was reviewed in order to: (a) provide an overview of research and change in the area; (b) choose and develop further an instrument; and (c) provide the methods for the construction and validation of the scales. At the end of this period of fieldwork and review of the literature, it was necessary to decide on the instrument to be used to collect accurately measured data on the strength and coherence of teachers' and students' views on STS issues. Structured teacher interviews, which used a modified form of the six questions trialled during the visit to the United Kingdom, were also conducted during this present Australian study. Thus there were complementary modes of data gathering in this Australian investigation.

The Choice of Methods for Gauging Respondents' Views on STS

After the initial literature review and field work to identify the focus of this study, and consideration of what was measured in this study (Chapter 4), it was important to consider the best way in which to examine views in relation to STS. Important questions which had to be resolved prior to the collection of data in this study to assess students' and teachers' and scientists' views, were: Is Aikenhead correct in assuming that views must be student oriented, or are Conant's views as interpreted by Cooley and Klopfer (1961) more valid? Alternatively, would the instrument employed by the International Association for the Evaluation of Educational Achievement (Comber and Keeves, 1973) be a more valuable one to use, since there were Australian data on this instrument available which were collected in 1970?

For this Australian study, there was a major question to be answered as to whether students had coherent views on STS issues. If the views of students at this stage of their education were not strong and consistent, the previously mentioned *TOUS* instrument (Cooley and Klopfer, 1961) might have been an instrument with greater internal consistency and validity, even though it imposed an adult level of consistency on the measurement of views on STS.

A study of science education in 19 countries in the early 1970s (Comber and Keeves, 1973) for the International Association for the Evaluation of Educational Achievement used a 15-item instrument, which drew heavily upon the *TOUS* tests in order to assess students' ability to understand the nature and methods of science. It was considered that the abilities called into play in responding to the items used in the test might bear some relationship to attitudes (Comber and Keeves, 1973). The review of the literature indicated that the TOUS instrument might, therefore, have provided a viable alternative instrument for this present study. However, the VOSTS instrument was chosen, since as discussed in Chapter 1, it was considered that the empirical development of the VOSTS instrument might allow students to interpret the meanings of the items more readily than other instruments, which were developed from the researchers' viewpoints. Furthermore, the trial run, followed by the use of item response theory indicated that students held coherent views on STS.

Ethics Approval for the Study

In order for the purposes and methodology of the investigation to be explained and for agreement to participate in the study to be obtained, letters were sent to school principals in November 1994. Subsequently, in January 1995, principals and science teachers were also contacted by phone to discuss the details of the administration of the survey and the conduct of the teacher interviews in each particular school.

At this stage of the study, ethics approval was granted by the Flinders University Research Ethics Committee and the Department for Education and Children's Services (DECS). The procedures for gaining ethics approval involved a large amount of paperwork to inform all of the educational authorities involved about both the rationale and the methodology for the study. In order to obtain ethics approval it was also necessary to ensure that informed consent would be obtained from all of the participants in the study, and that confidentiality would be maintained. Approval for this study was gained from the Social and Behavioural Research Ethics Committee, Flinders University of South Australia on the 16th of December 1994 (ethics approval number ESR 904). Ethics approval was gained from DECS on the 14th of February 1885 (ethics approval number DECS 3/40/197).

Data Collection Methods

There were two methods of collection of data used for consideration in this work. Data were collected through (a) a survey using the instrument that had been developed, and (b) interviews with teachers. The interviews with teachers enabled valuable discussions of the views, understandings and concerns of teachers in relation to the curriculum shift towards STS to be held. Moreover, the main advantage of using an instrument for the collection of data was that a relatively large amount of material could be collected efficiently from a substantial number of respondents. Data from a large sample were considered desirable, since the larger the sample of schools and students within schools the smaller the size of errors due to sampling. The use of a scaled instrument, as well as visits to schools were necessary as complementary data-gathering methods for measuring the shift towards STS in terms of students' and teachers' views of the issues. After measuring the students' and teachers' views in relation to the STS content of the new curriculum, it was possible to consider the way in which these views might affect the successful introduction and induction of the new upper secondary science curricula in South Australia.

Scales Used in the Study

Examination of the VOSTS instrument (Aikenhead et al., 1989) consisting of 114 items, led to the conclusion that it was important to limit the number of items administered in this study. Since these items were originally designed for Year 11 and 12 high school students in Canada, some of the items used terms or geographical examples, which were not appropriate for use with Australian students. Other items were excluded because they addressed an aspect with which this investigation was not concerned, or because they were based upon issues that had been addressed previously. Thus, for the pilot survey it was decided that a selection of items from the VOSTS inventory, written in a slightly modified form to suit Australian circumstances, would enable an effective survey of the views of a group of secondary students at the beginning of a curriculum change.

The main objective of the administration of the scaled instrument during this study was to measure the strength and coherence of students,' teachers' and scientists' views in relation to STS. Information on students' and teachers' views was gathered by using an adaptation of the VOSTS instrument developed by Aikenhead, Fleming and Ryan in 1987. Following the review of the literature and careful consideration of issues relating to validity, it was argued that since the VOSTS instrument was constructed using students' viewpoints, it was more likely to produce valid results, as discussed in Chapter 7. This instrument to monitor students' views on STS was developed by Aikenhead and Ryan (1992) in an attempt to ensure valid student responses so that the meaning students read into the VOSTS choices was the same meaning as they would express if they were interviewed.

Aikenhead and Ryan (1992) suggested, however, that the items used in the VOSTS instrument could not be scaled as the previously used Likert-type responses were. Aikenhead had worked within a qualitative, interpretative approach rather than the quantitative approach, and he had not realised that item response theory had advanced to the stage of encompassing a multitude of student responses rather than just two (Aikenhead, pers. comm., 1997). For the achievement of the aims of the present study, this view expressed by Aikenhead and Ryan was considered to be in error. The instrument used to gather viewpoints on STS in this Australian study was significantly strengthened by adding a measurement component to the work that had previously been done. This served to strengthen the conclusions arrived at as a result of the study. Mathematical and statistical procedures to do this had been advanced (Masters, 1988; Adams, 1991) and acceptance of Aikenhead's challenge to develop a measurement framework for the VOSTS items was of considerable significance.

The first step in this study was to examine whether the items in the VOSTS instrument could be dealt with in terms of scales that had sound measurement characteristics. This required the undertaking of a pilot study.

The Pilot Study

Aikenhead Ryan and Fleming had organised the VOSTS statements into nine major sections or domains within which items were formulated. The items for the trial of the instrument in this present study were chosen to form a cross-section of items from four domains of the original nine domains in the VOSTS instrument. These domains were:

- the influence of society on science and technology; (*Society*)
- the influence of science and technology on society; (*Science*)
- the characteristics of scientists; (*Scientists*) and
- the nature of scientific knowledge (*Nature*) (Aikenhead, Ryan and Fleming, 1989).

Domains and items were chosen to reflect the respondents' views on what were considered by Aikenhead, Ryan and Fleming to be the major issues of STS in Canada. These included:

- the influence of governments, the military, educational establishments, corporations, and special interest groups on science;
- social responsibility and decision-making of scientists both in wartime and in regard to the use of science and technology for practical problems in everyday life;
- the contribution of science and technology to economic and social well being;
- the capital-intensive nature of science and technology;
- unwanted side-effects of science and technology;
- the characteristics of scientists; and
- gender-related issues associated with science, technology and society.

After the pilot study for this present study, items from the fourth domain (*Nature*) were not included in the final instrument used in this present Australian study, since only six items remained after the selection process discussed in Chapter 7. Furthermore, it was considered that not all of the students from the range involved in this present study would be able to answer these six items in a valid way, since they seemed to involve knowledge and understanding to a greater extent than did the items in other domains.

An important advance in this present study was scaling of the instrument to measure students' views. Aikenhead had suggested that it was only possible to undertake qualitative research to examine students' views on STS. There was, however, a need to challenge Aikenhead's claim and to seek to measure students' views in relation to

STS. This would lead to the production of scales to measure students' views in relation to science, technology and society, using as a basis the VOSTS instrument.

The three scales, which were finally used in this Australian study, were developed from three of the VOSTS domains that related to:

- effects of society on science and technology (*Society*);
- effects of science and technology on society (*Science*); and
- characteristics of scientists (*Scientists*).

After the VOSTS instrument was redeveloped in an appropriate form for an Australian survey, a pilot study of 200 students in two metropolitan secondary schools in South Australia was undertaken. The schools for the pilot study in the metropolitan area were a non-government girls' school, and a non-government boys' school. These schools were chosen because they were convenient, represented both sexes, and the author had contacts in both schools.

Before the schools were visited, introductory letters explaining the purpose of the study, as well as samples of the instrument were sent to the school principals. In order to satisfy ethical criteria it was necessary to prepare and distribute a letter (including an attached consent form) that explained the purposes and methodology of the study to parents. Before students were involved in the survey, the consent form signed by the parent or guardian of each student involved in the trial was collected. The instrument was administered to students during two consecutive science lessons. The students required approximately one minute to complete each item.

The next step in the study after the pilot study data were collected, was an examination of the items in the scales in order to ensure that the instrument was in a form that was appropriate for use with South Australian students. Furthermore, an answer sheet was prepared by the end of January 1994. The student positions corresponding to each VOSTS statement were graded on a scale from 0-4, according to how strong and coherent in regard to STS each of the possible responses for each statement was considered to be. This examination and subsequent further development of the scales after the pilot study enabled the views towards STS of the teachers, students and professional scientists to be measured and compared. The methods used during the development of the scales in this present study are discussed in greater detail in Chapter 7.

On return, the instruments were first scanned to check for errors that would cause coding difficulties, for example, the circling of more than one response. After the pilot study in which the subset of 45 VOSTS items was trailed, the collected data were employed for scaling the items to form three scales, using Rasch scaling procedures. This trial of the survey instrument was important because, as discussed in Chapter 4, it was necessary to determine whether students held consistent views in relation to STS before embarking on this study which aimed to use the VOSTS instrument to measure students' and teachers' and scientists' views on STS. The Rasch model was found to be consistent with students' views, as discussed in detail in Chapter 7.

Development of the Final Instrument

Since it was found in the pilot study that students required longer than the length of an average lesson to complete the instrument, the pilot study instrument was reduced in length. It was reduced from 45 items to 27 items. The choice of the items to exclude was according to either intrinsic characteristics of the item such as inability to discriminate sufficiently, or too large a number of items from that STS domain to provide for a balanced instrument. The pilot study revealed some inadequacies in the way certain items were presented. The reasons are discussed in Chapter 7. The final instrument, which is shown in Tedman and Keeves (2001), was administered readily in a 40-minute period. The items and the final scores allocated to each of the responses in the items, after the validation of the scoring in the scales, is shown in Tedman and Keeves (2001).

After each response for each item, the scores are shown in parentheses. These scores are on a scale from 0 to 4; according to how strong and coherent the responses are in regard to the STS issues in the statements for the items. The 27 items used in this study formed three scales with the following composition: *Society* (9 items), *Science* (10 items) and *Scientists* (8 items). The items relating to each of the three scales were randomly separated from each other when the items in the instrument were ordered, in an attempt to discourage respondents from forming patterns of responses.

The analysis of the instrument to ensure that the calibration of the scales was in accordance with students' views was completed by June 1994. The aim of this pilot study was therefore to confirm the validity of the measurement of students' views so that the main testing program would proceed smoothly. Piloting the instrument also enabled an assessment of the adequacy of the answer sheet for the recording of students' choices. The final answer sheet was prepared at this stage by modifying the format and presentation slightly to ensure that clear responses could be given for each of the items. Some introductory pre-coded items and questions were added to the answer sheet in order to obtain personal and general information that was considered to be useful in identifying factors that influenced students' views on STS. This information was used as student level and school level variables that were examined in order to determine the relationship between these selected variables and the strength and coherence of students' views on STS. Table 5.1 shows the variables that were examined in this study after information was collected by the introductory questions and items on the answer sheet.

The Field Study

The second phase of the study began in February 1995. This phase comprised the field study, or administration of the instrument to 1278 students in the selected schools and 110 teachers. The group discussions with 101 teachers also occurred at this stage. In addition, 31 professional scientists were asked to respond to the scales in the instrument. It was considered important to measure the strength and coherence of the STS views of both teachers and scientists in order to provide information for the development of university courses in both science and teacher education.

The Selection of Schools for Investigation

Before selecting the schools for the study it was important to collect information from SSABSA on enrolment figures for South Australian senior secondary schools and colleges at the time the fieldwork for this study was conducted. A visit to speak to the Science Curriculum Officer at SSABSA led to the provision of a list of all the secondary schools, including the numbers of students in each school at the Year 12 level.

All types of school and all sexes of school as well as schools from both metropolitan and non-metropolitan areas were included in the sample, as shown in Table 5.2. The visits to schools to administer the instrument and conduct the structured interviews comprised the fieldwork for this study in South Australia.

Table 5.1 Variables and theoretical levels in the study

Constructs Level		Observed Variables
Student	Gender	Sex of student
	Home background	Father's occupation
	Home background	Mother's occupation
	Attitudes to School Science	Like science
	Efficacy in School Science	Marks in science
	Science subjects studied in 1995	Studied Physics (PES) in 1995
	Science subjects studied in 1995	Studied Chemistry (PES) in 1995
	Science subjects studied in 1995	Studied Biology (PES) in 1995
	Science subjects studied in 1995	Studied Biological Science (SAS) in 1995
	Science subjects studied in 1995	Studied General Science (SAS) in 1995
	Science subjects studied in 1995	Studied other science in 1995
	Expectations of future participation in education	Expectations of further education
	Expectations of future participation in science education	Expectations to include science subjects in further education
	Expectations of future participation in science	Expectations of science-based courses for further education
	Age	Age of student
School	Sex of school	Coeducational, single-sex boys or single-sex girls
	Type of school	Government or non-government
	Location of school	Metropolitan or non-metropolitan
	Socioeconomic status of school	Average socioeconomic status of student's father's occupation for a school
	Socioeconomic status of school	Average socioeconomic status of student's mother's occupation for a school

Table 5.2 Summary statistics for the schools chosen for this study

School Description	Number of Schools	Number of Students
Government Schools	18	846
Non-government Schools – Independent – Catholic	11	432
Metropolitan Schools	24	1038
Non-metropolitan Schools	5	240
Coeducational Schools	25	1085
Boys' Schools	2	92
Girls' Schools	2	101

The Procedure for the Selection of Schools

The procedure that was used in the study for the selection of schools was a probability proportional to size sampling procedure (Rosier and Ross, 1992). It consisted of a series of steps that culminated in the calculation of the sampling interval. The list of both government and non-government schools for the 1994 estimated student numbers from SSABSA was used so that schools could be selected using the ideas involving "tickets in a raffle" (Rosier and Ross, 1992). In this method, the approximate Year 12 numbers for each school were calculated from the school's estimated total enrolment of secondary students, and each Year 12 student was assigned one "ticket". A cumulated tally of Year 12 enrolments was then prepared, and sampling was performed at the constant interval that was determined by the calculation described below. In this way, the chance of selecting a school was proportional to the number of tickets held. In order to calculate the sampling interval, the following formula was used:

$$\text{Sampling interval} = \frac{\text{Total number of tickets}}{\text{required number of schools}} = \frac{635}{35} = 18.$$

The 35 schools chosen by this method were contacted, and from those schools that agreed to participate, all students of the Year 12 level were asked to respond to the instrument. It was considered, at this stage, that 35 schools would be a manageable size for data collection in the study. However it was found later in the study that this sample was smaller than expected, because it was not possible to obtain agreement from a large enough number of single sex schools, particularly girls' schools, to be involved in the study. Unfortunately it also took a long time to gain approval for the visits to some of the schools that were involved in the study. At the same time, the ACER was also mounting a large testing program using South Australian schools, and the ACER researcher showed an inability to collaborate. As a consequence, it was not possible to rectify the situation and thus have a greater number of single sex schools involved in the study.

Administration of the Instrument

When the 35 schools were contacted, it was found, unfortunately, that the industrial pressures in some of these schools in response to the South Australian Government's decision to limit the number of teachers, coupled with pressure to achieve high results for students in the South Australian Certificate of Education Examinations and the National Statement and Profiles in the lower secondary school, made it difficult to obtain agreement from the schools to be involved in the survey. One school, for example, could not become involved in the study because of staff industrial bans. Another school had already agreed to participate in a survey for the Australian Council for Educational Research in 1995, and did not wish to commit the school to another study. A further school had just had a rather serious fire, and hence did not want to risk any further disturbance to the studies of their Year 12 students. Eventually, however, after a great deal of careful negotiation a 74 per cent response rate was obtained, since 26 of the 35 schools chosen agreed finally to be involved in the study. In order to increase the number of schools in the sample, it was necessary to repeat the selection procedure or re-draw to provide nine extra schools. By this stage it was rather close to the beginning of the school year, so only three more schools agreed to be involved in the study, giving a total of 29 schools. Moreover, of these 29 schools, which were involved in the study, only 23 groups of science teachers (110 individuals) agreed to respond to the scales, and only 101 teachers agreed to be involved in the interviews. The scales were administered to 1278 Year 12 students and 110 senior secondary science teachers. The teachers were asked to respond to the scales during the school visits.

Thirty-one scientists also completed the instrument, in order to enable a comparison of the strength and coherence of the STS views of students, teachers and scientists. The scientists were either National Health and Medical Research Council Fellows or Members of the Australasian Association for the History, Philosophy and Social Studies of Science. Although teachers responded to the scales, it was considered that structured group discussions with teachers in the schools visited during the study would also provide an extremely important component of the investigation of this shift in curriculum in South Australian schools.

The Group Discussions

The disadvantage of multiple-choice instruments is that they restrict responses. It was hoped to gain richer and more interesting information on the views of teachers in relation to the curriculum shift towards the inclusion of STS. As a consequence, in each school group interviews of teachers were conducted. Open-ended questions formed the basis of group interviews with teachers in each school that aimed at obtaining information on how the teachers saw the curriculum changes that were taking place. These interviews or group discussions with 101 teachers were important methods of gathering information for this study, and are discussed in Chapter 10. Structured group interviews with teachers were considered preferable to individual interviews, since they provided the observations of the group of teachers discussing the planning of the curriculum within schools.

The following questions formed the basis of group discussions with teachers:

- What is your understanding of STS? Why teach STS?
- How do you incorporate STS into your subject teaching?
- What resources do you use for teaching STS?
- Do the students respond well to STS material? Do girls respond particularly well to STS material?
- A strand of the Statements and Profiles for Australian Schools is 'Working Scientifically'. What is science, and how do scientists work?
- What do you see as the main issues in STS courses?

Statistical Procedures Employed in This Study

A comprehensive range of statistical procedures was used to analyse the data collected during this study. This study aimed to produce a master scale for views on STS by scaling a selection of the VOSTS items. It was considered extremely important to analyse the data in a way that enabled significant correlations between factors at both the student and school levels to be shown and the coherence of students' views on STS to be tested.

The Rasch Model for Scaling Items

In this Australian study Rasch scaling was used, as mentioned above. Rasch (1960) proposed a simplified model of the properties of test items, which, if upheld adequately, permitted the scaling of test items on a scale of the latent attribute that did not depend on the population from which the scaling data were obtained. This system used the logistic function to relate probability of success on each item to its position on the scale of the latent attribute (Thorndike, 1982, p. 96).

Thus, the Rasch scaling procedure employs a model of the properties of test items that enables the placing of respondents and test items on a common scale. This scale of the latent attribute, which measures the strength and direction of respondents' views towards STS, is independent of the sample from which the scaling data were obtained as well as being independent of the items or statements employed. Furthermore, Wright (1988) has argued that Rasch measurement models permitted a high degree of objectivity, as well as measurement on an interval scale.

A further advantage of the Rasch model was that although the slope parameter was considered uniform for all of the items used to measure the strength and direction of students' views towards STS, the items differed in their location on the scale and could be tested for agreement to the slope parameter, and this aided the selection of items for the final scales.

The Consistency of the Scales

Before proceeding with the main data collection phase of this study it was necessary to calibrate the scales and establish the consistency of the scales. The consistency of the scaling of the instrument was established using the data obtained from the students on their views towards STS. The levels of strength and coherence of students' views were plotted so that the students who had strong and coherent views on STS when compared with the views of the experts were higher up on the scale. At the same time the items to which they had responded were also located on the common scale. In this way, the consistency of the scales was established.

Validation of the Scales

It was considered important to validate the scales used in this study to measure respondents' views in relation to science, technology and society. In order to validate the scales, a sample of seven STS experts from the Association for the History Philosophy and Social Studies of Science each provided an independent scaling of the instrument (see Chapter 7). A further method of validation was provided by a detailed review of the literature relating to the STS issues that formed the basis of the items in the instrument. The discussion of this literature is provided in Chapter 6. Thus, the validation of the scales ensured that the calibration of the scales was strong enough to establish the coherence of respondents' views with those of the experts. Thus validation tested how well the views of respondents compared with the views of the experts. Furthermore, the initial scaling of the responses associated with each item was specified from a study of STS perspectives in relation to the STS issues addressed by the items in the questionnaire. The consistency and coherence of the scales and each item within a scale was tested using the established procedures for fit of the Rasch model to the items.

Analysis of Data

After the processing and entry of data, analysis of the data proceeded with the preparation and printing of histograms for the students' data, and the printing of the data for students and teachers. The statistical computer packages QUEST (Adams and Khoo, 1993) and Statistical Package for the Social Sciences (SPSS) were used to analyse the data file created. The research questions were then addressed using statistical techniques.

Processing and Entry of Data

The entry, processing and analysis of data (Stage 3) commenced in May 1995. The first step was to organise or classify the data into an appropriate numerical form for entry into the Statistical Package for the Social Sciences (SPSS) program. This involved converting the letters of the students' responses into numbers. In the cases of the responses to the questions on occupation, *An Occupational Classification of the Australian Workforce* (Broom, Jones and Zubrzycki, 1965) provided the appropriate classification. The students' ages were converted to months, the schools were assigned a number according to the order in which they were visited, and male students were coded- 1, whilst female students were coded- 2. The types of schools and school sector were also assigned a numerical code.

Subsequently, it was necessary to prepare the SPSS program for the entry of the data from this particular study. Preparation of the program consisted of adding the table headings for each type of data that were to be entered, and then the meaning or significance of the data codes in each table. Since the alternative viewpoints on the statement of each of the 27 items was assigned a number, it was necessary to type each coded viewpoint into the program for the purposes of analysis. The SPSS file for the entry of the data from the teachers' instrument was then prepared in a similar way. The data were then entered. It was also necessary to prepare information for the cleaning of the student data and the teacher data so that valid relationships and correlations within the data could be established. Any inconsistencies resulting from incorrectly coded data were located, checked and corrected according to the original students' and teachers' answer sheets, and then re-entered.

In order to deal adequately with this large amount of quantitative data it was considered necessary to couple the SPSS package with the QUEST statistical package for the data analysis. Consequently, the next step was to prepare a file for SPSS for use with QUEST. An input command program for use with 27 items was prepared. The student responses which were in numerical sequence were recoded in order to scale them, or convert them to the quantitative score values that were devised previously. The data were converted to ASKII format. The program was then run, and the print out was checked. When allocating scores to the items in the scales used in this present study, missing data were given a 0, since these respondents could be classified with the last three alternatives, for students who couldn't make up their minds. The SPSS program was then used to produce the means, standard deviations and frequency distributions. The testing and calibration of the scales is described in detail in Chapter 7.

Contingency Tables

These subgroups of interest were investigated by using the cross tabs statistical function of the SPSS package. The χ^2 values and degrees of freedom (DF) summarised in contingency tables were used in this study to determine if a relationship was significant. This was accomplished by using the Table of critical values of χ^2 (Ferguson, 1959) to determine the critical value corresponding to the degrees of freedom for that particular relationship. This was then compared to the χ^2 value divided by two if a characteristic of the student was one of the variables in the contingency table. The χ^2 value was divided by four for a school characteristic. Thus, the χ^2 values were corrected for cluster sampling by division by an estimated design effect of 2 or 4 as considered appropriate. If the adjusted χ^2 value exceeded the critical value, then the relationship was regarded as significant. This corrected value of χ^2 was tested by the customary χ^2 test procedures. This crude correction for the design effect of the sample was suggested by Kalton based on the estimates advanced by Peaker (1975).

If a significant correlation was established, the next step was to identify which of the responses to that item was responsible for the significant correlation. The responses with a substantial difference between the values of the column percentages were further investigated. The nomograph provided by Oppenheim (1992) was used in testing for a significant effect.

Analysis of Variance

Analysis of variance was used with the three scales to examine the statistical significance of the effect of a number of variables on the strength and coherence of students' views towards STS. These variables included:

(a) science subjects studied in 1995,

(b) marks in science,

(c) ©liking of science,

(d) location of school,

(e) type of school,

(f) years of further education,

(g) inclusion of science subjects in further education,

(h) future course of study,

(i) future occupation,

(j) mother's occupation, and

(k) father's occupation.

After an analysis of variance was performed for each of the three Rasch-scaled scores the significance tests were performed and the effect sizes were determined. For comparisons that involved intact school groups a correction was made for the use of a cluster sample by dividing the F-ratio by an estimated value of the design effect of four. Where the comparisons involved the consideration of subgroups that cut across schools the correction made for the use of a cluster sample required division of the F-ratio by the estimated value of the design effect of two. This correction may be expressed in the following way.

$$\text{corrected F} = \frac{\text{F-ratio}}{\text{estimated design effect}}$$

This corrected value of F was tested by the customary F-test procedures. This crude correction for the design effect of the sample was based on the estimates advanced by Peaker (1975).

In addition to the test of statistical significance, an effect size was calculated. This was accomplished by determining the magnitude of the differences between the means relative to the combined standard deviation and the following equation was used:

$$\text{effect size (d)} = \frac{\text{the difference in the means}}{\text{combined standard deviation}}$$

The convention advanced by Cohen (1969) was used to indicate whether the effect sizes were large, medium, small or trivial. This classification of the size of an effect is:

(a) $d > 0.8$ the effect size is large;

(b) d is between 0.5 and 0.8 the effect size is medium;

(c) ©d is between 0.2 and 0.5 the effect size is small; and

(d) $d < 0.2$ the effect size is trivial (Cohen, 1969).

Groups are highly separated if there are large differences between them, e.g. the differences in height between 13 and 18 year old girls is 0.8 (Cohen, 1969, p. 25).

Hierarchical Linear Modelling

Educational researchers often need to take account of nested data, with students nested in classrooms, schools, universities, districts, states or countries. In this study, student- and group-level characteristics influenced each other, for example, sex of student influenced sex of school. In order to be able to use analysis of variance with traditional statistical techniques it is necessary to ensure that factors at one level are not influenced by factors at another level. This is sometimes accomplished by random allocation of students to groups. There was no random allocation of students to groups in this study, so there was clustering of data in a hierarchical form. When data are at different levels, problems arise from the use of simple random sampling procedures that are assumed when traditional techniques of statistical analysis are employed.

Consequently, in this study, it was considered important to use two-level hierarchical linear modelling (HLM) to test for effects that had occurred both within and between schools. The details of the HLM analysis in this Australian study including the models, the variables and the results of the two-level multivariate analysis are discussed in Chapter 12. In this chapter the initial steps in the multilevel analysis are described and an overview of this method of statistical analysis and its benefits are given.

In real-life processes in education, as discussed above, different factors operate at different levels. In this study, at both the student-level and school-level there were linear models, and these models had a hierarchical structure, since students were nested within schools. This nested structure would have introduced mismatched precision and an aggregation bias if traditional statistical techniques were used for all of the analyses (Raudenbush and Bryk, 1994). Thus, the class of models used in this study took the nested structure of the data into account. The use of HLM also allowed the formulation and testing of hypotheses about cross-level effects and the consideration of both within- and between- school components (Bryk and Raudenbush, 1992).

With respect to this procedure Hox has written:

> The goal of the analysis is to determine the direct effect of individual and group level explanatory variables, and to determine if the explanatory variables at the group level serve as moderators of individual-level relationships. If group level variables moderate lower level relationships, this shows up as a statistical interaction between explanatory variables from different levels. (Hox, 1995, pp. 5-6)

The HLM2 program was used for multilevel analysis after using dummy coding for categorical variables. The hierarchical linear model was viewed as a hierarchical system of regression equations (Raudenbush & Bryk, 1986; 1992). In this present study, the model at the student level (Level- 1) was built around explanatory variables that included student sex and father's occupation. The program centred the data, or shifted the axis to a central position, so that the intercept was more meaningful. This grand mean centering thus facilitated the interpretation of the variables included in the equation. The slopes of the lines as well as the intercepts were taken as outcome measures. The dependent variable was the coherence of students' views on STS. It was considered that it was possible to set up a separate regression equation for each school to depict the effects on the dependent variable Y by the explanatory variable X. These equations are discussed in Chapter 12.

Each school had its own characteristic intercept and slope coefficients, so they were referred to as random coefficients. The next step in the development of the hierarchical linear model was to introduce explanatory variables at the school level.

The level-2 model included school level explanatory variables in order to predict the variation of the regression coefficients. Complex regression models were then developed. After this, the HLM/2L package used the maximum likelihood estimation procedure to compute maximum likelihood estimates for the regression coefficients and variance components by an iterative procedure. Thus the estimation steps were repeated (iterated) many times in order to attempt to obtain convergence, or a minimal change in the likelihood function for the estimates that the program generated of values for the various parameters in the model.

Multilevel modelling was, therefore, a procedure in which the researcher suggested explanatory models by using variables hypothesized as possibly significant on the basis of the review of the literature from previous studies. Simple models were investigated first, and then other variables were included in a sequential process. After each step, the results were inspected to see if the effects were significant. The χ^2 test and the deviance were used as a formal test of the improvement of fit between the model specified at a particular step and the model from the previous step.

This process eventually allowed the best possible models to be developed. Moreover, HLM provided p-values as an indicator of the significance of parameter estimates. The HLM2 output also included the variances and covariances at the two levels, the deviance, parameter estimates and their standard errors (Hox, 1995). After the simple models were tried, other models were tested. The results were inspected to see which explanatory variables were significant.

Re-calculation of Standard Errors

Examination of the output from the calculation using SPSS of means, standard deviations and standard errors for each of the three scales indicated that the initial standard error calculations for the students were incorrect, because they were based on the assumption that a simple random sample had been employed in this study. The WesVarPC program (Brick et al., 1996) was used for the subsequent calculation of accurate values of the standard errors. This program used a jackknife procedure to allow for the fact that the sample used in this study was a cluster sample, with schools sampled at the first stage and students drawn from within schools at a second stage.

By dropping one school out of 29 schools at a time in replications of the analyses, which were undertaken, the program obtained 28 different values for the parameters estimated in this study. With these values, the program calculated the mean and the standard deviation of these parameters and used these newly-calculated values to estimate the new mean and the new standard errors, which were more accurate than those calculated in other ways.

The calculations were only performed for the student group, because this was the only group of respondents who were identified by school when the data were originally entered. The original data file was also adjusted to account for the possibility of obtaining perfect scores (see estimating logits, Chapter 7). A weight variable was created using the data from the original SPSS file. However, the data were not changed, since each observation was weighted with a one. The program thus prepared the data before estimating the means and sampling errors. The analyses discussed above enabled conclusions to be drawn, and recommendations to be made.

Summary

The issues for investigation during this Australian study were identified by both the literature review and a ten-week visit to Britain, since in the British National

Curriculum STS objectives were a prominent feature of science courses. Ethics approval was obtained from both DECS and The Flinders University of South Australia. The trial of the instrument during the pilot study enabled the final instrument to be developed in an appropriate form to measure the strength and coherence of respondents' views on STS.

The schools for the main study were selected from lists of the enrolment figures for South Australian senior secondary schools and colleges provided by SSABSA, which included student numbers in Year 12 classes. The sampling interval for the choice of schools for the main study was calculated to enable a sample with probability proportional to size of the Year 12 enrolment for 1995. The principals of these schools were contacted by mail and by telephone, so that they were able to understand all aspects of the study well, before agreeing for the students and staff of the school to be involved in the study.

Twenty-nine metropolitan and non-metropolitan schools from the government, independent and Catholic sectors were visited, so that the instrument could be administered to 1278 students and 110 teachers. During the school visits, group interviews were conducted in 23 schools with 101 teachers. The discussion, in these interviews, of teachers' opinions and concerns in relation to the shift towards STS, was based upon six topics. The instrument was also administered to 31 scientists, to enable a comparison of the strength and coherence of the STS views of students, teachers and scientists.

Statistical techniques were used in the study to measure respondents' views on STS and to examine the factors affecting respondents' views on STS. First, in order to examine the large amount of data collected during the study, SPSS was coupled with QUEST (Adams and Khoo, 1993). Secondly, since the data were nested at different levels, HLM (Bryk, Raudenbush and Congdon, 1994) was employed to allow the examination of both the effects at different levels, and the interactions between the effects at different levels. Accurate standard errors were calculated using the WesVarPC program (Brick et al., 1996) because the sample was a complex random sample.

Issues of consistency and validity were important considerations in this Australian study. The consistency of students' views was established using Rasch scaling. In the pilot study, the adapted VOSTS instrument was administered to approximately 200 students in two metropolitan secondary schools in South Australia. This pilot enabled the adequacy and consistency of students' views to be tested. The procedures to be employed in the calibration of scales in a way that was in accordance with students' views were also tested during this trial. The validity of the scaling was established by both a review of the literature, and an independent scaling provided by a panel of the experts. The validation of the scales by review of the literature is the topic of the next chapter.

6

The Validation of the Scales from STS Writings

The instrument used in this study was scaled so that a quantitative determination of the students', teachers' and scientists' views in relation to STS would assist in the investigation of this important aspect of a curriculum change in secondary science courses in Australia. These factors, and others, which might affect the success of the curriculum change were subsequently investigated by multilevel analysis procedures using the HLM program as well as by the structured interviews with teachers.

The scales used to measure respondents' views in relation to STS were validated in two ways. The first method of validation was founded upon the assertion by Lucas (1975) that the validity of such instruments rested upon theoretical positions within the philosophy of science. As a consequence of the need identified by Lucas to validate the instrument in this manner, theoretical positions within the philosophy of science are discussed in this chapter. Theoretical positions with regard to the sociological foundation of Science, Technology and Society are also examined. In addition, the theoretical positions of the authors that guided the development of the original VOSTS instrument are considered.

The second method of validation consisted of the independent scaling of the questionnaire by seven members of the Association for the History, Philosophy and Social Studies of Science, who had extensive expertise in the area. The response pattern of these experts was then compared with the initial scaling of the VOSTS items on the basis of the review of the literature discussed in this chapter as well as the judgment of the researcher.

Content and Construct Validity from STS Writings

The scales administered during this study were designed to measure views with regard to three aspects of the interrelationship between science, technology and society. The three dimensions that comprised the scales were (a) *Society*, (b) *Science* and (c) *Scientists*. In this chapter on the content and construct validity of the scales, each item that was included in the final scales is addressed in order to validate the scaling of the responses. Case studies and examples of particular technologies that have been applied in society, as well as in the lives and discoveries of particular scientists, are discussed below in order to provide examples to support the initial scaling of the questionnaire. As Conant (1966, p. vi) suggested, the use of case histories of exciting scientific events is extremely fruitful, since it illustrates “the tactics and strategy of science” as well as the “growth of scientific research as an organised activity of society”. This discussion therefore illustrates relevant STS issues and provides the framework and evidence for the scaling of the items included in the scales that were used in this study. The items in the instrument, as well as the scaling of the responses for each question, are shown in Tedman and Keeves (2001).

The Effects of Society on Science and Technology (Society)

The values, political and economic ideologies and priorities, and the religious ideas of a society have a profound effect on the science and technology that are funded and developed within that society. This has been the case throughout history. The situation for scientists in Nazi Germany illustrates the way that politically-imposed criteria can modify or curtail scientific activity, since Hitler’s criterion of Aryan supremacy led to a purge of eminent Jewish scientists and discordant scientific ideas (Merton, 1973). Furthermore, the progress of science was also adversely affected by condemnation from the Catholic Church of Copernicus’s hypowork of the heliocentric universe, as this was contrary to the prevailing religious idea of the universe as a system of closed concentric crystalline spheres, which was divinely created and maintained (Bernal, 1965).

In contemporary, developed societies, the progress of science and technology is influenced by a number of significant factors. These factors form the basis of the following discussion of the *Society* scale of the instrument used in this present study.

The Institutionalisation of Science

Discussion of the sociological nature of science demonstrates that, in the view of eminent scholars, subjectivity in science is produced by interactions between social institutions. This discussion also establishes the basis for subsequent consideration of the effects of society on science and technology. The institutionalisation of science, for instance, has been responsible, at times, for directing science in a manner that supports the vested interests of members of other institutions.

Academic science was seen by Barnes (1985) as a social institution connected through a vast range of interdependent relationships to other social institutions such as governments, educational establishments and the military. Barnes (1985) contended that after science became a social institution, its role was to develop and modify existing knowledge. This was in sharp contrast to the roles of other fields of learning, where the aim was to preserve and perpetuate existing knowledge. As Barnes maintained, the importance of this institutionalisation of science was that the practitioners of science and other citizens and institutions with a vested interest in the continuation of the enterprise became its supporters without any regard to rights and wrongs, thereby profoundly affecting the direction of science and technology.

Any discussion of student responses to the VOSTS items should be presented in the context of the philosophical understanding upon which STS is based (Lucas, 1975), as discussed in Chapter 1. Fleming (1987), one of the researchers who developed the VOSTS instrument, agreed with Lucas. He also supported the use of the sociological model of science as a social institution or a subculture of society for the development of the VOSTS items.

Proponents of this sociological model of science have maintained that subjectivity in science has arisen through conflicts between science, technology and institutions such as governments, corporations, special interest groups and religious organisations (Gaskell, 1982; Cutcliffe, 1990). These conflicts were also responsible for guiding research and innovation in science. This effect was further exacerbated by the questions that were asked in the production of the scientific information as being directed by political and moral judgments (Gaskell, 1982). Moreover, Fleming (1987) concluded that rather than being merely transmitted, scientific knowledge was changed as a result of the interaction between the institution of science and other cultural institutions. As Fleming argued, technology has its own cultural resources, so the development of new technology and the continuation of the old were also affected by the interactions between technology and other social institutions.

The Institutionalisation of Science in Australia

The institutionalisation of science in Australia began with the setting up of research institutes to coordinate the national research effort. The first Australian research institute with political independence, though responsible to a Minister of the Federal Government, was the Council for Scientific and Industrial Research (CSIR), which was established in 1926 under the terms of the Science and Industry Research Act. The CSIR became known as the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in 1949 when the act was further modified to remove defence research to the Department of Supply (Encel and Ronayne, 1979). Since the major research and development in Australia was initially directed towards primary production, a research institute had already been set up in South Australia for agricultural research. The Waite Institute was established in 1924 as a focus for agricultural academics and postgraduate students (University of Adelaide, 1996).

With the development of international competition in the late 1950s, however, university research began to be deliberately encouraged by the Commonwealth and State Governments. This eventually led to the establishment of the Australian Research Grants Commission (ARGC) in 1965 in order to provide financial support for outstanding research workers in Australian universities (Encel and Ronayne, 1979).

The ARGC became the Australian Research Council (ARC) in 1989. In 1997 the objective of the Large Research Grants Program of the ARC was to award grants to support Australian research likely to lead to:

a) a significant advance in an understanding and knowledge of a subject, through conceptual advances and discoveries; or

b) practical outcomes of importance to the research endeavour itself and to applications of social and economic value. (Australian Research Council, 1995, p. 18). This context for Australian science and technology highlights the importance of discussing the control of science in Australia by the Commonwealth and State Governments and corporations as well as the influence of education, educational establishments, and special interest groups on the direction of science and technology in this country. It is also important to consider the effects of national priorities on the allocation of funding for Australian science. These aspects of STS in Australia are discussed below.

The Influence of Governments on Science (Items 3,9,19, and 25)

The items in the scales, which relate to the influence of governments on science, consider the issues of funding and direction of research by the Australian government, and the effect of politics on Australian scientists. These issues, which involve interaction between social institutions, are considered in the context of the institutionalisation of Australian science.

The institutionalisation of science policy in the machinery of government in the second half of the twentieth century resulted from the need to create specific administrative arrangements for research funding, since the resources devoted to science and technology were growing at a rate which exceeded that of the Gross National Product in many developed countries. Careful formulation of policy in regard to science and technology was necessary to ensure that these enterprises continued to benefit humankind. A definition of science policy has been provided by Encel and Ronayne in Australia in the following terms:

> ..the collective measures taken by governments to encourage development of scientific and technological research activities, and to apply the results of these activities to social and political ends. (Encel and Ronayne, 1979, p. 1)

During the Second World War, scientists showed that they could achieve results that would previously not have been considered possible in other circumstances, and the belief in the powers of science was clearly established (Encel and Ronayne, 1979). Special advisory bodies of scientists to shape science policy were set up in the years that followed the experiences of coordinating research and development during the Second World War. These advisory bodies included the Ministry for Science and Technology in Australia, which was first set up in 1966 to shape science policy (Cross and Price, 1992).

The result of the institutionalisation of science in Australia is that institutions become coupled to or sustained by science and technology, and science and technology become locked into the general institutional structure of society. Outsiders to the scientific enterprise can count upon its continuation by relying on the goods it produces, thereby creating vested interests and subsequent support. It is important for science to be well controlled and coordinated in Australia. However governments have vested interests that may result in science being steered in directions without moral or ethical considerations (Gaskell, 1982). Thus, as Item 25 Response B suggests, the government’s control of science should depend upon how useful the particular research would be for Australian society. Useful research should be more closely controlled and money should be provided. The primary goal of the Australian Federal Government’s science policy has become the encouragement of innovation as a factor contributing to economic growth and social welfare (Commonwealth of Australia, 1994).

In developed countries including Australia, science programs are shaped by both financial support from national budgets and taxation policies that encourage spending on research and development (Cross and Price, 1992). The taxation incentives to encourage Australian companies to increase their expenditure on research and development have increased in recent years, as the Government introduced the 150 per cent tax concession that applied to research funding from July 1985 (Industry Research and Development Board, 1994). This concession has allowed companies to reduce the after-tax cost of their research and development to around 50 cents in the dollar. Apart from taxation incentives, governmental control of science in Australia, through funding, is in the form of the allocation of research grants by research agencies and funding bodies, including the Commonwealth Scientific and Industrial

Research Organisation (CSIRO), the Australian Research Council (ARC), the National Health and Medical Research Council (NH&MRC), the Australian Nuclear Science and Technology Organisation (ANSTO) and the Australian Geological Survey Organisation (AGSO) (Sheehan, 1994).

A feature which has distinguished Australia's research and development funding system from that of other OECD countries is the domination of the funding of research and development in Australia by the Commonwealth and State Governments. The contribution by the Commonwealth and State Governments to the Gross Expenditure on Research and Development (GERD) in Australia is 58 per cent, which is considerably larger than that in most other developed countries (Sheehan, 1994). Consequently, a further problem of the exclusive control of science by government in Australia stems from the excessive rigidity, uniformity, and centralisation associated with government departmental organisation (Ronayne, 1984).

This rigid arrangement is not ideal for the promotion of effective research and development, since it erodes the autonomy of the scientific community. The view that it is necessary for scientists to be provided with the link they need between their autonomy and the performance of successful, creative science is supported by Merton's discussion of challenges to the scientific ethos by external authority. Merton (1973) suggested that the sentiments embodied in the ethos of science, including impersonality, intellectual integrity, organised scepticism and disinterestedness, would be preserved only if the scientific community remained autonomous. Problems arose when the State imposed a new set of sentiments upon scientific research, and scientists resisted such changes, since scientists had an emotional investment in their way of life, that was defined by the institutional norms that governed their activity (Merton, 1973). This assertion supported the claim that the government should not have exclusive control over science and technology in Australia.

The Commonwealth Government should coordinate research that would be useful for Australian society. The responsibility of government to the Australian taxpayers and the community should be to ensure that a substantial proportion of the taxpayers' money is spent on projects that would be useful for improving the quality of life and caring for the environment. The level of gross expenditure on research and development (GERD) in OECD countries varies greatly, and Australia lies well down the list. The 1994 GERD for a sample of countries was: (a) Japan 3.07 per cent, (b) Germany 2.73 per cent, (c) France 2.42 per cent, and (d) Australia 1.36 per cent. The major reason for Australia's comparatively lower investment in research and development has been that the business sector in Australia has made a relatively poor contribution to research and development. In Australia, the Commonwealth and State Governments contribute 58 per cent to the overall GERD, while the contributions to GERD made by the Japanese and West German Governments are 10 per cent and 34 per cent respectively (Sheehan, 1994). As a consequence, it is extremely important that Australian Governments continue to provide money for research that would be useful for Australian society.

The need to provide scientists with autonomy, coupled with the vested interests that might influence governmental control of science, has the implication that governments or community agencies should not simply tell scientists what to investigate. Furthermore, national budgets and taxation priorities should be decided on economic and political grounds with little consideration to science, since often the people who make the decisions have very little understanding of science (Cross and Price, 1992). Therefore scientists should also contribute to decisions on what they would investigate. This view has been supported by the experiences of promoting and coordinating scientific research and development during the Second World War, when it was demonstrated that it was necessary for government agencies and scientists together to promote the development of science and technology (Snow, 1971). Consequently as written in Item 9, Response C, it is important that government agencies and scientists together should decide what needs to be studied by scientists.

Research of a variety of types in Australia occurs in universities, government research organisations and private corporations. As well as employing science and technology to advance Australia's economy, researchers in Australian universities make a substantial contribution to pure research, much of which is not directly related to immediate human benefit, but which adds to the body of scientific knowledge about the world. Fletcher (1979) concluded that university research made an important contribution to the nation, and the emphasis was more on the advancement of knowledge than other research objectives including national security, economic development and community welfare. In order to fund research that could be expected to produce favourable social or practical benefits the priority areas nominated by the Australian Research Council for 1997 research grants are:

(a) Biology of Sustainability,

(b) Citizenship,

(c) ©Exploration Geophysics,

(d) Food Science and Technology,

(e) Minerals Processing Science and Technology, and

(f) Optics. (Australian Research Council, 1996)

Response A and Response B in Item 19 offer the cogent observations that as members of society, Australian scientists are influenced by politics, since governments, which provide most of the funding for scientific research, control the way the money is spent by formulating science policy and deciding which research areas to support. Furthermore, although research funds in Australia are allocated largely according to priorities such as those discussed above, the ARC provides some support for university researchers on the basis of merit, and not necessarily according to national priorities. Australian scientists consequently have to compete for research funds, and sometimes have to lobby for funds, thus politics have a direct effect upon the development of scientific knowledge. The competition for funding is so great that scientists are now provided with the opportunity to nominate up to three persons known to them who are qualified to assess their project (Australian Research Council, 1996). This was introduced so that the assessors chosen were not people who would be influenced by a personal dislike of the candidate, thereby limiting their chances of success.

Thus in Australia, university research and research by scientists from research organisations such as the CSIRO has been funded on the basis of historical evidence of the benefits of scientific knowledge. As stated in Item 3, Response C, even though it is often impossible to tell ahead of time whether the research is likely to be beneficial or not, it is an investment risk which should be taken. Response D in Item 3 offers the further rational suggestion that the funding of scientific research is a necessary investment on the basis of the belief that by understanding the world better scientists would make it a better place in which to live. Nossal (1983) noted that science and technology have been embraced by people all over the world because they work. In the light of this exposition it is important that the Australian governments should give scientists money for their research. Since the ability of developed industrial societies to cope with future emergencies depends on the strength and balance of research today (Ferne, 1979), there is a great need to fund and promote research that would enable the achievement of important social and environmental priorities for the Australian nation.

The future of life on earth would be improved by the invention of helpful technology and more advantageous use of nature's environment and resources. The Australian government should, therefore, provide scientists with research money to explore the curious unknowns of nature and the universe. This research funding would result in the use of nature's environment and resources to the best advantage, as well as the invention of helpful technology.

The Influence of the Military on Science. Case History: Scientists in the Second World War (Item 23).

The framework for Item 23, which deals with scientists' and technologists' decisions to work on military research and development is provided, in this section, by discussing the case history of scientists' work on military research during the Second World War. The experience of funding military technology created a precedent for further funding and control of research and development in this area in succeeding years. Although the social impetus and method for the application of science are similar in times of peace and times of war, during war, science and technology are pushed forward vigorously under the impetus of fear of loss and hopes of profit that war alone could bring (Bernal, 1965). The case history of the Tizard Committee and the development of radar during the Second World War provide an example for the consideration of the influence of the individual scientist's values, and research interests, as well as of personality conflicts on the choice of an area for research and development.

Sir Henry Tizard was successful in gaining a large amount of money for the development of the technology of radar during the war years. Snow's (1971) account of the contribution of the Tizard Committee to the defence policy decisions of the English Government during the Second World War shows how scientists are able to influence the allocation of major research funds. The Tizard Committee was so-called because its chairman, Sir Henry Tizard, was well placed in academic and social life, and this prominent social position assisted Tizard greatly in his career as a high-level scientific administrator (Snow, 1971).

Tizard was successful in convincing the English military officers of the great promise of radar. Tizard encouraged scientists to attempt to ensure that science caused more good than harm. He did this by suggesting that when giving military advice, scientists should ensure that the advice was sound by convincing themselves that if they were responsible for an action, they would themselves act accordingly (Snow, 1971). This suggestion stands in recognition of the need for scientists to be aware of the effects of their experiments ahead of time and to accept some of the responsibility for undesirable outcomes.

In the light of the above discussion it is important to consider government funding of military research, since this is an area which some individuals in particular societies would not consider to be a priority for the funding of research. However, many governments in advanced societies have provided large budgets and recognition for work in the area of military research. As Cross and Price (1992) reported, from early times a large proportion of government funding for science and technology in many countries has been allocated to military research. However, since governments recognise that the benefits from funding science and technology include economic well being, social welfare, and increased quality of life (Badger, 1979) health and agriculture have also received support for programs of research and development.

A total of $921 million was provided to the major Australian research agencies in 1994-95, including $219 million on defence Research and Development, and $125.5 million to the NH&MRC, although there was a further $27.0 million allocated to other health Research and Development (Commonwealth of Australia, 1994, p. 3). The Defence Science and Technology Organisation (DSTO) received funding of $215 million during 1994-5 (Sheehan, 1994). For 1995-6 the Australian budget allocation for the Defence science and technology function was $225 million (Commonwealth of Australia, 1995, p. 5.5).

In view of the power of this research funding to entice scientists to work on military research, it is important to consider the actions of individual scientists in order to allow for both the human failings as well as the strengths that would guide the scientists' decisions and actions. Conant presented this cogent conclusion based on his observation that:

> ...as human beings, scientific investigators are statistically distributed over the whole spectrum of human folly and wisdom much as other men. (Conant, 1947, p. 8)

Since scientists' values influence their choice and definition of research problems (Bernal, 1965), some scientists might choose to use the large amount of money offered for military research to further their own research interests. Other scientists, however, would rather not work on projects related to war, as these projects would conflict with their values. The choice of whether or not to do research for the military depends, therefore, on the person's values and research interests. As contended in Item 23, Response C, some scientists would find the military projects interesting and rewarding; other scientists would rather not work on projects related to war.

The Influence of Special Interest Groups on Science (Item 12)

If, as indicated above, science policy in Australia is controlled by the Minister for Science, who directs science and technology to the achievement of social and political ends, then what factors influence the Minister in the development of policy and who determines which social and political ends and priorities need to be met? Item 12 in the questionnaire that deals with the influence on science and technology research by special interest groups such as environmentalists and religious organisations addresses this question.

In the quest to win votes or financial support at the time of elections Governments might be influenced by special interest groups. Special interest groups include people who feel concerned about environmental issues that range from nuclear power to wood chipping. Item 12, Response D, maintains that these special interest groups consequently have the ability to influence science and technology in Australia, since they influence government policy, and governments decide whether to fund a research project or not.

An Australian program, Science and Innovation Policy Analysis, was developed in 1994 to provide an informed basis for discussion and policy advice for relevant decision-makers and interest groups by monitoring, analysing and interpreting information on Australia's science, innovation, research and technology system. It is significant for this discussion that the target audience for this program included interest groups and media as well as government, parliament, firms, industry, research organisations, academia and the bureaucracy (Department of Industry, Technology and Regional Development, 1994). This cited target audience is an open acknowledgment of the influence of interest groups and the media upon policy-making in Australia.

Special interest groups that have mounted widespread resistance to certain developments in science and technology in recent years include the international movement against nuclear power, occupational health and safety groups, the group against the United States' defoliation campaign in Vietnam (Albury and Schwartz, 1982) and the environmental movement, Greenpeace. In Australia, special interest groups have been successful in achieving many of their environmental goals by entering into politics. In some cases, such as in Tasmania, their success has been due to their representatives holding the balance of power in parliament. In Tasmania, "Green Politics" groups have been particularly successful, and have been active in issues such as the Franklin hydro-electric scheme, the Wesley Vale wood pulp mill and logging (Cross and Price, 1992).

The Influence of Educational Establishments on Science (Items 5 and 21)

Education has a significant effect on the success of science and technology in Australia in terms of the public support for science and the quality of the graduates in science and engineering. In Item 21, which deals with the influence of education on science and technology in Australia, it is maintained that since the success of science and technology depends on the provision of good scientists, engineers and technicians, Australia should require students to study more science at school. The influence of education on the support of science by a more informed public was the topic of Item 5.

The strongest force for the continuation of the scientific enterprise in the community has been that graduates of science who were trained in a certain traditional way have moved out into the community and have used their scientific and technological knowledge for applied research to produce goods which can be translated into capital. This has constituted a substantial contribution to the economies of advanced nations such as Australia, and a self-sustaining inter-dependency. As a consequence of the research funding provided by governments, academic institutions have been able to continue to fulfil their side of the interrelationship between science and government by supplying expertise and advice, thereby infusing their knowledge into the community (Barnes, 1985).

Science policy decisions have a profound effect upon life in modern societies. Consequently it is important that informed citizens take a role in directing science and technology to ensure they serve community values and interests. Item 21, Response D, conveys the rational view endorsed by many prominent researchers in STS (Bybee, 1987; Cross, 1990; Yager, 1990a, b; Heath, 1992), that as more students learn about science and technology, the more informed public will be able to form sound opinions and make effective contributions to how science and technology are used. Fleming (1987) defined science as the process of understanding natural phenomena and technology as the process of designing techniques and instruments to respond to human needs. Thus an informed public would be able to ensure that technology served human needs.

The continuation and success of science in contemporary societies also depends upon how much support the informed public provides for science. In order for the public to be sufficiently well informed to support science and make sound decisions on how science and technology are used in society, it would require a high standard of technological and scientific literacy. Technological literacy could be developed through appropriate kinds of science courses, with an STS focus, which would prepare students for their lives in a world of 'sociotechnology' and by teaching effective decision-making skills (Fleming, 1989).

Through STS courses, the science education of students is matched more closely to their needs as members of societies which are increasingly dependent upon technology, by moving from conceptually-dominated courses to courses that stress the social relevance of the work being covered (Fensham, 1988a). Unfortunately, traditional science courses are directed almost entirely toward acquiring information and inquiry skills, and there is little evidence that such courses help students to develop cognitive skills in a manner which would enable them to use this acquired knowledge in their daily lives (Yager, 1990b). There is, therefore, the need for a new kind of science course which would enable students to improve their own lives in society by dealing responsibly with the many STS issues which affect their daily lives (Yager, 1990b; Cross and Price, 1992).

New directions for science teaching require a shift towards a science curriculum that can be lived and which blurs the distinction between schooling and the real world (Yager, 1990b). Lowe (1990, p. 330) has argued that "significant reform of the education system" was necessary to make informed public decisions possible. He contended that as society had always been significantly shaped by technology, ensuring that the future public would be better informed about STS issues was of particularly high priority. Scientific and technological knowledge has enormous potential to reduce suffering if the imparting of this knowledge could be accompanied by an informed and open public debate about the risks, benefits, and monetary and social cost of the technology (Gesche, 1995).

Many South Australian science teachers support this need to design and implement new kinds of science courses which would enable their students to think critically about issues in the world around them, and how their students might be empowered to act in relation to these issues. These teachers seek to assist their students to become thoughtful, scientifically literate citizens who would be able to make informed decisions about STS issues (Hattam, 1994).

The above discussion leads to the conclusion that there is a need for educational systems to provide students with opportunities to consider the interactions between science, technology and society as well as instructing them in the basic scientific knowledge. This need is examined in the questionnaire by the inclusion of Item 5, Response C, which suggests that students should be required to study more science in school in the form of a different science course that would enable the students to learn how science and technology affected their everyday lives.

The Control of Science by Corporations (Item 15)

Item 15 is based upon the issue of the control of science by corporations. A case history of genetic engineering provides a useful example for a discussion of the control of science by corporations. In the early years following the inception of genetic engineering (recombinant DNA technology) there was concern about the potential dangers of recombinant DNA techniques. This concern included anxiety that: (a) humans would have the power to determine their own evolution; (b) experimentation in genetic engineering would lead to ecological imbalances (Freifelder, 1978); (c) moving animal genes into bacteria could create pathogens (Weissbach and Skalka, 1979); and (d) the products of genetic engineering research could be used in warfare (Larrick, 1983).

These concerns over the safety of genetic engineering technology resulted in the setting up in 1975 of an international meeting of 134 genetic engineering scientists from 19 countries. This meeting culminated in the development of the National Institute of Health (NIH) Guidelines, which defined restrictions and safeguards for use in genetic engineering research (Straton, 1977).

The initial fears over the safety of recombinant DNA technology have largely receded, but the latest developments in the field present many value-laden issues. The ultimate aim of the Human Genome Project is to locate about 100,000 genes on human chromosomes. Information about the location, function and connection of these genes to disease is being stored in a variety of computer data bases, and will have important implications for medicine, biotechnology, and, in fact the entire community (Keleher, 1993). In the case of the Human Genome Project there are many ethical issues involved in order to protect human rights.

The case history of the development of genetic engineering highlights the need for community agencies as well as scientists to have some influence on what should be investigated in science. Furthermore, the story of the introduction of genetic engineering techniques has provided a useful example of the interaction between science and government, since recombinant DNA became a political issue, and the consequences of the use of science and technology were recognised as being too important either to be left to the self-regulation of scientists, or to be regarded as being apolitical (Freifelder, 1978).

The development of genetic engineering technology has also served as a focus for consideration of the interactions between science and industry, since a serious problem arose with the guidelines for development. Industry, and those individual scientists who contracted with industry, were able to avoid inspection under proprietary laws, and were initially left free from any constraint imposed by the NIH Guidelines (Simring, 1978). Multinational corporations were keen to exploit the success of genetic engineering technology during this initial period (Kerr, 1982). Although the guidelines required detailed reporting of proposed recombinant DNA experiments, this requirement was difficult to enforce, as it ran counter to the protection of proprietary interest (Grobstein, 1977).

This discussion of the development of genetic engineering illustrates the problems that could occur if corporations controlled science, the topic of Item 15. Their scientific discoveries would be restricted to those discoveries that benefited the corporation. Corporations might also be silent on important scientific and technological work conducted by their scientists, which carried the potential for some disadvantageous social or environmental effects. It was asked in Item 15 whether corporations should mainly control science. As in general for cases involving the control of scientific research by corporations, the question that should be asked is whether the powerful forces of the profit motive would lead companies to exploit that area of science and technology without any thought as to the safety and consequences of their work.

The Effects of Science and Technology Upon Society (Science)

In addition to the influence of social institutions and individuals on the development of science and technology, innovations in science and technology have a significant effect upon life in contemporary societies. Developments in science and technology such as military equipment, genetic engineering, reproductive technology and other biomedical technologies hold such great potential for benefit or harm that it is important to consider carefully the use of the products of scientific research. These products of science could also challenge the value systems of society and cause humans to pause and consider the priorities and moral guidelines for research and development. Public debate on the development of new technologies is clearly essential for the future quality of human life.

Over time, philosophers and sociologists have been largely responsible for changing the community's perception of science. The other force involved in changing the community's perception of science has resulted from the challenges to values, by the application of scientific knowledge to the solution of social problems. The discussion of the scaling of the responses in the *Science* scale of the questionnaire focuses upon the issues resulting from the effects of science and technology upon society, many of which present substantial challenges to the value systems of societies.

Social Responsibility of Scientists (Item 10)

The case history of *The Manhattan Project* is discussed in this section in order to provide a framework for consideration of the social responsibility of scientists. The issue of whether Australian scientists should be held responsible for the harm that might result from their discoveries formed the basis of Item 10. The issue is best addressed by using case histories of the role of scientists in the development of technologies that have potential for causing great physical harm, or for presenting serious challenges to the moral fabric of society. The development of the atomic bomb highlighted the importance of the interrelationship between science, technology and government, since the very close partnership that developed between science and government in the United States resulted in large sums of money being provided to finance this development (Bernal, 1965).

An account of the development of the atom bomb serves to illustrate what was arguably the first time during the twentieth century when an important and influential group of scientists became aware of the need to accept responsibility for the serious consequences of their work. As Solomon (1988) suggested, the notion of social responsibility in science might well have had its genesis with the development and dropping of the bomb and the Oppenheimer situation, as scientists such as Oppenheimer saw the need to accept responsibility for the results of science and technology.

Philosophical considerations by these scientists of the effects of their discoveries would have challenged the values of the twentieth century. Weeramanty (1983) suggested that even the scientists who were responsible for the development of the atomic bomb did not appreciate the frightening overall consequences of their work until it was too late for them to withdraw from the project. The atom bomb was the mightiest weapon that had ever been developed, due to the vast quantities of energy that were liberated by uranium fission (Massey, 1953). Furthermore, it represented the greatest and most expensive scientific effort of the time, the result of which was the loss of 60,000 lives at Hiroshima and 30,000 lives at Nagasaki (Bernal, 1965).

A substantial public reaction was, therefore, induced by the development of this potentially devastating product of science. The assertion was made that the new discoveries in physics had allowed human beings far too much influence over natural phenomena. Until that time, scientific discoveries seemed to have little to do with the realities of everyday life as people perceived them. This transformation of the scientific view of nature was comparable to the change of outlook brought about by Copernicus (Jungk, 1958). After the explosion of the two atomic bombs, the recognition that citizens had a role to play in determining the direction of the use of science and technology in society, and taking some responsibility for the harm that might result from scientists' discoveries, began to surface.

Consideration of events in the life of the Hungarian physicist, Szilard, also provides an example of the interaction between science and politics, as he was passionate in his considerations of how society and the environment would be affected by the generation of atomic energy. Szilard's belief that scientists should accept some responsibility for the effects of their work or discoveries led him in 1945 to prepare a warning letter for President Roosevelt. It was stated in this letter that any military advantage the bomb might bring to the United States would be offset by grave political and strategic disadvantages (French and Kennedy, 1985). After considering the moral implications of resorting to the use of atomic bombs to force Japan to surrender, Szilard wrote in his petition to the President of the United States that:

> Such a step, however, ought not to be made at any time without seriously considering the moral responsibilities which are involved. The development of atomic power will provide the nations with new means of destruction. The atomic bombs at our disposal represent only the first step in this destruction and there is almost no limit to the destructive power which will become available in the course of their future development. Thus a nation which sets the precedent of using these newly liberated forces of nature for purposes of destruction may have to bear the responsibility of opening the door to an era of devastation on an unimaginable scale. (French and Kennedy, 1985, pp. 459-450)

This was a well-considered statement, and it is significant that since the end of 1945 when the world was made aware of the discovery and development of nuclear power, as Jungk (1956) suggested, it has been possible to see the fission of the atom as a turning point in global history.

The first atomic weapons were designed and manufactured under the direction of Oppenheimer in 1942 (Ronayne, 1984). The ruling political ideology of the time had a significant influence on Oppenheimer's career, and this demonstrated the profound effect on scientists and science of social factors such as political systems. Oppenheimer had displayed some sympathy with communist causes, and was friends with some members of the Party during the earlier years of his life. Oppenheimer's wife had also been a member of the Party.

This expression of sympathy with communist causes and the political affiliation of Oppenheimer's wife, were used against him later in his career. When it became known in the United States that the Soviet Union had also developed an atomic bomb, the counter move was to develop a more terrible hydrogen bomb, and it was opposition to this development that was the real cause of Oppenheimer's downfall (Bernal, 1965). In November 1953, President Eisenhower received documentary material compiled by Hoover, in which the opinion was expressed that Oppenheimer was probably a Soviet agent in disguise. President Eisenhower responded by ordering the erection of a blank wall between Oppenheimer and all government secrets. Oppenheimer was presented with a letter by the Atomic Energy Commission that contained 23 paragraphs dealing with his associations with communists. Questions were raised as to his conduct, loyalty and credibility (Jungk, 1956).

During the ensuing trial of Oppenheimer in 1954 the debate in the courtroom concerned not only Oppenheimer's fate, but all the unsolved problems that the atomic age presented to scientists. They had a new part to play in society, with the prospect of complete destruction presented by their creations, and a new set of ethics, beliefs and values was required. Many reflective scientists had been greatly concerned about atomic power since the beginning of the project, and now they were drawn right into the storm centre of politics (Jungk, 1956).

This case of a scientist, Oppenheimer, being concerned about the effects of developments in science and technology, established the precedent for scientists to be concerned about negative effects which may result from the use of science and technology in society. In more recent years, the development and implementation of genetic engineering technology, which led to the National Institute of Health (NIH) guidelines, also provided for the continuation of the trend of the need for scientists to take some responsibility for the harm that may result from their discoveries. As stated in Item 10, Response C, scientists should be held responsible for the harm that might result from their discoveries because they must be aware of the effects of their experiments ahead of time. Science should cause more good than harm.

Science for the Solution of Practical Problems in Everyday Life (Item 1)

The statement that knowledge of science and technology helps in the solution of practical problems in the everyday lives of citizens was included in Item 1. The way in which the systematic reasoning taught in science classes helps in the solution of practical problems is discussed in this section in relation to the aims and goals of contemporary science courses and curricula.

The relevance of science for everyday life, with respect to its use in decision-making and problem-solving, is not a concept that students acquire automatically by completing several science classes, since in traditional science courses, students are not specifically taught how to make critical connections between academic subjects and their outside lives (Cobern, 1995). The National Curriculum in Britain had actually been fuelled, in the 1980s, by considerations of the need for more effective teaching including problem-solving, investigation, discussion and the development of those understandings, skills and attitudes which would help students see the relevance of their studies for their everyday lives (Windale, Hudson and Smith, 1995). Students would then be able to see the relevance of their scientific studies, and use their knowledge of science to explain and understand a wide variety of physical events at subsequent stages in their lives.

One of the goals of science education, scientific literacy, has been defined as empowering students “to be able to understand and apply basic scientific concepts to everyday situations” (Cobern, 1995, p. 28). The aims and goals of science education in the 1990s have also been discussed in relation to a liberal education. A liberal education contributes to a person’s ability to draw upon their understanding of science as relevant to various intellectual and practical tasks. These include understanding both themselves and the universe of which they form a part. Other aims of modern science education include equipping students with everyday skills such as the development of critical thought needed for decisions on the practical issues that are presented to citizens in modern scientific societies (Davson-Galle, 1994).

Two other important goals of science education are to develop students’ ability to read critically and to develop their problem-solving ability (Koch and Eckstein, 1995). The problem-solving approach has been employed in science since Galileo. Not only does this approach work for practical problems, but it can also give science students understanding of the world and help them make better use of the science they learn (Malcolm, 1992b). An effective science education would, therefore, as stated in Item 1, Response D, lead to the continuation of the use of the systematic reasoning and ideas learnt in science classes to help citizens to solve certain problems and understand a wide variety of physical events throughout their lives.

Contributions to Social Decisions in Relation to Science and Technology (Item 16)

In an energy-dependent society such as Australia, decisions on the types of energy that could be used in the future are extremely important. The statement in Item 16 dealing with this issue is that scientists and engineers should be the ones to decide what types of energy Australia would use in the future because scientists are the people who know the facts best.

Unfortunately, decisions in relation to the use of science and technology in developed societies are often made by people who have very little knowledge of science and technology (Cross and Price, 1992). Scientists and engineers should be involved in these decisions, since they are the people who know the facts. Discussion of STS issues relating to the development and introduction of technology highlights the need for scientists to be active in the formation of science policy to guide the direction of research in Australia. Scientists should be aware of the potential effects of their work, and inform members of the public of these potential risks and implications of their work.

However, the implications of decisions on whether to use renewable energy sources, or sources such as coal burning or nuclear power, which have serious environmental implications, are so significant that it is important not to allow these decisions to be made by scientists alone. It is everyone's responsibility to ensure that science and technology are directed towards the solution of problems such as pollution, since the informed public should have a say in what science tries to achieve in modern societies.

The need for the Australian public to play an informed role in decisions on the use of science and technology in society was supported by a recent Australian survey on public attitudes to the use of biotechnology such as genetic engineering. In the study it was concluded that it was necessary to have an educated community, which was able to evaluate the advantages and disadvantages of technologies to be used in society, so that the public could share the responsibility with the scientific community (Gesche, 1995). Furthermore, Gesche (1995) strongly supported the view that the public ought to have a right to know, and to participate in the decision-making process in regard to science and technology.

Cross and Price (1992) discussed the citizens' responsibility for taking a part in decisions relating to science and technology. The authors argued that otherwise, decisions such as those involving the distribution of energy, sewage and water would be technically functional, but often without serving the interests of local communities. This suggestion supported the conclusion that the viewpoints of the informed public as well as the viewpoints of scientists and engineers should be considered in decisions which were related to the types of energy Australia would use in the future. The need for all intelligent citizens to consider that energy decisions were of highest priority was stressed by Conant (1947). The implications of these decisions in contemporary energy-dependent industrial societies such as Australia are significant.

Barnes agreed with this view and drew attention to the need to ensure that science continued to serve human purposes Barnes stated unequivocally that:

> We ourselves have to take care that the connection between science and human ends is as we would have it. And, however long the connection remains as we would have it, we must nonetheless never allow ourselves to forget its contingency and insecurity. (Barnes, 1985, p. 12)

In contemporary societies, the role of education in helping students to participate in an intelligent way in discussions on STS issues is becoming increasingly important

(Cross and Price, 1992). Thus, STS objectives have been included in many senior secondary science curricula, in order to equip citizens to take an informed part in decision-making on the development of science and technology (Yager 1990a; Zoller 1990; Heath, 1992; Yager, 1993).

Since science and technology are considered to have a social role in advancing human well-being and national interests, the close link between science, technology and society generates social, moral and ethical issues for citizens (McConnell, 1982). In many countries, the traditional authority of governments to make decisions on science and technology alone has been challenged, and governments have responded by developing mechanisms such as public enquires, science courts and information dissemination, to increase public participation in decision-making (Gaskell, 1982). Consequently, as stated in Item 16, Response D, decisions on issues such as the types of energy Australia would use in the future should be made after considering the viewpoints of scientists and engineers, other specialists, and the informed public.

The Contribution of Science and Technology to Economic Development (Items 2 and 22)

Item 2 is based on the contribution that science and technology will make to economic development. The initial statement in the item is that the more Australia's science and technology develop, the wealthier Australia will become. This statement is discussed in relation to the views of experts on the economic benefits and other consequences of research and development in science and technology. The second aspect of the contribution of science and technology to economic well being, which featured in Item 22, was concerned with whether or not more technology would improve the standard of living for Australians.

In the past decade, the role of science and technology in Australia has undergone some profound changes in order to enable Australian industry to be more innovative and internationally competitive (Sheehan, 1994). The benefits of scientific research have featured prominently in government publications, in an effort to encourage further developments in science and technology that will enable Australia to be more competitive internationally. Recent government publications advocating increased investment in the development of science and technology, including the *Innovation Statement* (Commonwealth of Australia, 1995) released in 1995, suggested that new demands upon the science and technology system in Australia resulted from an export base which was rapidly changing from commodity production to the generation of high value-added goods and services. The *Statement* also addressed the need to optimise the capacity of the science and technology system to adjust to new market forces in order to achieve Australia's objectives in trade and investment. The goals of the *Statement* related to the need for Australia to become a centre for training and education in science, technology and engineering as well as to develop a strong, active applied science sector which was able to capture the commercial benefits of its achievements (Commonwealth of Australia, 1995).

The objective of the Science and Technology Awareness Program of the Department of Industry, Technology and Regional Development in Australia was to increase awareness of the central role which science and technology played in Australia's economic and social well-being. This was particularly important in regard to their role in innovation, and in enhancing the international competitiveness of Australia's manufacturing and services sector (National Board of Employment, Education and Training, 1994).

Barnes (1985) has suggested that scientific research is an investment, which delivers the goods, and returns a yield on the capital invested. Science is integrated into the economy and the overall system of production in Australia. It is, therefore, important that Australian science and technology develop in order to contribute to the economy, because Australia could sell new ideas and technology to other countries for profit. However, as Barnes has suggested, it is important to make a distinction between investment yields and real human benefits. The ability to increase Australia's wealth by investing in science and technology also depends on which outcomes of science and technology are supported. Some outcomes are risky. The Australian *Innovation Statement* reported as one of the emerging issues for the *Statement* that there was a "need for an improved ability to measure risk, and the impact of limited project management skills" (Commonwealth of Australia, 1995, p. 1.9). As stated in Item 2, Response D, whether or not science and technology will increase Australia's wealth depends on which science and technologies Australia invests in. Some outcomes are risky. There might well be other ways besides science and technology that would create wealth for Australia.

An important social implication of the use of science and technology is that some technology is capital-intensive and tends to replace humans in labouring positions (Lappe and Collins, 1977). Technologies such as advanced computing facilities have been condemned by some as a direct cause of widespread unemployment.

In the late 1960s and early 1970s, there was a great deal of concern that computerisation would both cut back on the growth of new jobs and reduce the number of existing jobs, such as clerical positions. It was suggested that computers reduced the range of job choices available to semi-skilled people, since the new jobs that were created were either highly specialised work for an elite group of computer programmers, or a greater number of machine-minding or routine jobs like key-punch operators. Microprocessors expanded into areas of life that were never before thought to be applicable to that type of technology (Trans-National Co-operative, 1978). It was even suggested that:

> In a way, the introduction of computers into the workplace is just the latest continuation of scientific management methods which began when Henry Ford established the world's first assembly line in his Detroit car factory. The result of this process has been the continual fragmentation and trivialization of work. Its objective is to reduce the workers' understanding of and control over the work they do and thus to remove their power in the workplace. (Trans-National Co-operative, 1978, p. 14)

The more critical public attitude towards scientific and technological developments that began to develop towards the end of the 1960s led to a levelling off or a decrease of the funding for science and technology in developed nations (Ronayne, 1984). Although high levels of economic development had been achieved largely through developments in science and technology, the sceptical attitude of many citizens towards science led to the establishment of an expert group from the OECD to investigate the implications of this new attitude towards science. The OECD group found that the adverse community opinions of science and technology focused on issues such as the general deterioration in the quality of life that had resulted from the use of science and technology in society, and ethical problems that had arisen from the developments in the biological sciences (Ronayne, 1984).

Item 22, Response E, concurs with these opinions since it suggests that more technology may or may not improve the standard of living for Australians. More technology would make life easier, healthier and more efficient. However, more technology would cause more pollution, unemployment and other problems. The standard of living may improve, but the quality of life may not. This concern for the employment problems initially caused by the development and introduction of computers has been discussed above. The use of energy-producing technologies has also caused environmental pollution (Saddler, 1981). More technology would make life easier, healthier and more efficient. More technology, nevertheless, might cause more pollution, unemployment and other problems.

As science and technology have become built into the social fabric of developed countries such as Australia, a logical consequence of this sociological view of science would be conflict in the interrelationships between science, technology and society. The serious discrepancy with regard to the use of science and technology to solve social problems lies in what science provides in the way of knowledge and what humans want by way of meaningful existence. Although advances in science and technology have led to economic development in countries such as Australia, it is unwise to assume that the development of science and technology would, on its own, continue to increase Australia's wealth, as it depends on the technologies adopted. Some outcomes would be risky, and would not satisfy neglected social needs, since severe structural changes would arise out of the disparity between different professions, occupations and industrial sectors (Ronayne, 1984). These technological innovations might also use environmentally degrading techniques, and this could represent a long-term drain upon the economy.

Unwanted Effects Caused by the Application of Science (Item 17)

Item 17, on the positive and negative effects of science and technology on society began with the statement that it was always necessary to make compromises between the positive and negative effects of science and technology. In the past 30 years there has been much discussion about the benefits and disadvantages of the reliance upon the exclusive use of technology to solve problems that might be more easily solved by other means. The overall problem with the application of technology to the solution of a vast range of social problems is that societies become increasingly dependent upon the "technological fix".

As Etzioni and Remp (1973) have written, it was not wise to have great faith in technological shortcuts. Their findings after examining several technologies which had been applied in an attempt to alleviate social problems, including methadone in controlling heroin addiction, antabuse in treating alcoholics, and methods of birth control such as the oral contraceptive pill and the Intra Uterine Device, were that each of the technologies worked, in that it allowed a significant reduction of the problem faced. Unfortunately, unwanted consequences of the use of the technologies in society, or side effects, were produced when the technology was applied. In 1961, for instance, soon after the introduction of the oral contraceptive pill, reports began to circulate that the oral contraceptive pill caused serious circulatory problems including pulmonary embolisms and thromboses (Inman and Vessey, 1968; Vessey and Doll, 1968).

These side effects, or "cracks" as Conant (1947) described them, are evidence of the fact that there is often the need for compromise between the benefits and negative effects of science and technology. It is also possible to conclude, after an examination of technologies, such as the oral contraceptive pill and the intra-uterine device, that although people who simply wanted a method of contraception, and did not suffer from side effects, benefited from this technology, the technology had negative consequences for those women who suffered from some of the more serious side effects. As stated in Item 17, Response C, developments in science and technology that benefit some people might have negative effects for others. Whether there are trade-offs between the benefits and negative outcomes of science and technology depends on a person's viewpoint. The moral implications of using contraception for women of the Roman Catholic Faith, by way of example, would seem to indicate that the effects of technologies for the individual would also depend upon a person's values and viewpoint.

The Effects of Capital-intensive Technology (Items 7 and 24).

The case history of the Green Revolution provides an example of the effects of capital-intensive technology in developing countries. In developed countries, science and technology have led to economic development and a less labour- intensive lifestyle, but pollution problems have arisen as a consequence of technologies such as heavy industry. Item 7 suggested that a responsible decision would be to move heavy industries to underdeveloped countries where pollution was not so widespread. Some attempts to transfer and apply technologies to underdeveloped countries have not been entirely successful, so these attempts are discussed in order to provide a framework for the consideration of whether or not moving heavy industry to underdeveloped countries would be a responsible way of solving pollution problems in developed countries. In a second question on pollution, Item 24, there was concern about pollution problems that were unsolvable today. This item continued with the statement that science and technology would not necessarily fix these problems in the future.

The compelling statement in Item 24, Response E, that science and technology alone cannot solve pollution problems, is an important consideration for developed societies such as Australia, where reducing pollution is everyone's responsibility. The public must insist that resolving these problems is of high priority, and education in STS would engender the achievement of this aim by empowering and informing citizens to take part. Ehrlich, Ehrlich and Holden (1970) supported this view when they stressed that although technology could provide massive assistance to pollution abatement, there was no universal technological remedy for pollution problems. The authors proceeded to emphasise that in their view, the solutions to environmental problems involved changes in human attitudes and participation in social decision-making in relation to these problems. The suggestion that heavy industry should be moved to underdeveloped countries where pollution was not so widespread was irresponsible. As stated in Item 7, Response D, developed countries should reduce or eliminate their own pollution, rather than create greater problems elsewhere.

Science, Technology and the Social Fabric of Society (Items 14 and 26)

Developments in science and technology are so important in establishing the social fabric of contemporary societies that science and technology can even assist people to make legal decisions: for example deciding if a person is guilty or not guilty in a court case. This was the area addressed by Item 14, while Item 26 focused upon the statement that science and technology have influenced our everyday thinking by giving us new words and ideas.

It is, therefore, important not to lose faith in the benefits of science and technology, since science and technology can work in contemporary societies to cure diseases and produce devices that make life easier and richer for many people. Conant (1947) maintained that the natural tendency for citizens to recoil from these decisions in relation to technological developments, in the wake of the horror caused by the atomic bomb, was ill-founded in the light of the many benefits for humans such as penicillin and anti-malarial drugs, cures for disease, transportation, communication, and the many luxuries that have resulted from scientific research.

Modern DNA typing technologies such as DNA identification analysis, identity testing, profiling and fingerprinting benefit humans by providing evidence in court cases. Item 14, Response D, focused on these ways in which science and technology can help in deciding whether a person is guilty or not guilty in court cases by developing ways to gather evidence and by testifying about the physical facts of a case. DNA "fingerprints" or profiles have been used in forensic science in legal cases of homicide, rape and assault as a valuable source of evidence for deciding if a person is guilty or not (Kirby, 1992). Kirby's conclusion is highly significant for this discussion as he maintained that:

> ..the point is that DNA analysis alone can be a definitive test. Once the technique becomes routine, there is little doubt that, provided a suitable specimen can be obtained, DNA fingerprinting will be the single best test for excluding a falsely associated individual. (Kirby, 1992, p. 3)

The technique of DNA fingerprinting operates on the principle of the uniqueness of the individuals' DNA structure in all tissues of the body. In this DNA typing technology, particular genetic base-pair sequences (or "mini satellites"), which are repeated in the body's genetic make-up, are isolated and cleaved using specific enzymes. A complex ladder of DNA fragments is detected by hybridisation under low-stringency conditions with a probe consisting of the core repeat and a profile, which appears to be unique for each individual, is obtained (Kirby, 1992).

Science and technology have influenced the everyday thinking of members of contemporary advanced societies. As stated in Item 26, Response D, science and technology are extremely powerful influences on the everyday thinking of humans, since almost everything humans do, and everything around them, has in some way been researched by science and technology. The impacts of new products of science and technology upon society is far-reaching in terms of their potential for affecting the organisation of work and their potential for challenges to deeply held ethical positions of members of society. Consequently, there is a sense of urgency felt by members of society about the impact of technological change on their lives and the time needed to adjust to each change (Gaskell, 1982).

The knowledge basis of this huge impact upon society can only be encapsulated into words to a small extent, and yet technological applications and techniques diffuse into and form the context and the foundation of everyday considerations and thinking for humans in contemporary societies. Therefore, although the physical environment is extraordinarily intricate and rich in information, only a small number of selected features of any situation find expression in terms of the few thousand words and signs which are available, and much more is comprehended and stored in the memory without being verbalised (Barnes and Edge, 1982). Science and technology have not influenced everyday thinking by providing new words and ideas, but by producing new inventions, tools and techniques, and this has provided the basis for the development of human thinking. Science and technology are extremely important forces for the construction of contemporary societies, and, in turn, science and technology are constructed by social forces. As Taylor and Huckstep (1992) have alerted:

> Technology is socially constructed. It gives shape to the material world, and ways of social organisation. The existing technology "structures" mirror back to us the way we see the world. Thus technology also constrains our possibilities for thought, our visions of what is possible. In the extreme it is called technological determinism. (Taylor and Huckstep, 1992, p. 1.2.5)

The Characteristics of Scientists (Scientists)

Science is value-laden, and the beliefs and values of individual scientists may affect the progress of science and technology in society (Merton, 1973; Longino, 1983; Dreyfus, 1995). Scientists' beliefs and values might also affect their observations or their choice of an area of research. Thus, as the discussion in Chapter 2 indicated, philosophical analysis of the nature of science has led to the conclusion that science is not always a completely objective body of knowledge. Scientists as humans cannot always be fully objective, since they are influenced by their beliefs and values (Kuhn, 1963; Longino, 1983). As a consequence, consideration of the effect of the characteristics of scientists on the direction of science and technology is important for the measurement of views of science, technology and society. The value-laden nature of science and the assumption that the values of scientists form the basis for their consideration of the ethics of their scientific work, are important in this discussion of the *Scientists* scale.

The previous discussion in this Chapter of the experience during the Second World War of the development of weapons in the *Manhattan Project* provided an example of the development of the social responsibility of scientists. The realisation, by scientists, that their ideas and inventions could have a catastrophic effect upon humans in all societies, has caused scientists to reflect upon the new part they have to play in society. The ethics, beliefs and values of scientists are extremely important for the future of societies. Scientists, as human beings, are affected by social factors, and, in turn, society is affected by the ideas and inventions of scientists. The characteristics of individual scientists have a great effect upon the progress of science and technology in contemporary societies. In this section, the influence of the characteristics of scientists upon the progress of science and technology is discussed.

The Effect of the Personal Characteristics of Scientists on Science (Items 6 and 18)

The work and choices made by scientists are greatly influenced by social factors and individual values and personal characteristics. Contemporary academic scientists employ logic, patience and accepted scientific techniques as the basis for their daily work, since some of their time is spent on routine problem solving within the boundaries of the accepted paradigm. The validity of their findings is ensured, in most cases, by the requirement that scientists publish their work so that it may be criticised by their colleagues (Riggs, 1992).

This influence of the characteristics of scientists upon the advance of science was discussed by Goldstein and Goldstein (1978), when they used Rumford as a case study. Rumford investigated the production of heat by friction in the boring of cannons, and his work moved knowledge of heat closer to the modern concept of heat as disordered atomic motion. The authors suggested that Rumford's favourable results were due to prophetic guesses, originality and determination, rather than as a result of adhering to the accepted scientific paradigm and methods of the time. Goldstein and Goldstein (1978) concluded that Rumford's success was partially due to the fact that he did not fit the common stereotype of scientists as being objective, not emotionally involved in their work, and quite willing to discard theories that were consistently contradicted by research results. This discussion supports the suggestion in Item 18, Response C, that although the best scientists are very open-minded, logical, unbiased and objective in their work, these personal characteristics are not enough for doing the best science. The best scientists also need other personal traits such as imagination, intelligence and honesty.

This view that personal characteristics such as conceptual imagination, curiosity, and obsession with ordered thought are necessary for the best scientists to make their individual contributions to the body of scientific knowledge has been supported by Ziman (1980). Furthermore, as Ziman has suggested, this kind of successful research depends on the individuals' experience, and the personal judgment, strategic decisions and choice of research topic and method made by individual scientists.

Bradbury, Oppenheimer's successor as director at Los Alamos director said at the trial, in answer to a question about the characteristics of scientists:

> Scientists are human beings. A scientist wants to know. He wants to know correctly and truthfully and precisely. Therefore I think you are likely to find among people who have imaginative minds in the scientific field individuals who are willing, eager, to look at a number of other fields with the same type of interest, willingness to examine, to be convinced and without *a priori* convictions as to the rightness or wrongness, that this constant or this or that curve or this or that function is fatal. (Jungk, 1956, p. 293)

The development of scientific knowledge is dependent upon the contribution of individual scientists whose personal characteristics and methods have enabled them to perform the routine day-to-day problem-solving activities of science as well as to make major advances in science. Consequently, the routine work of scientists operates within the boundaries of paradigms, and patience and determination are required for absolutely correct results. As stated in Item 6, Response B, patience and determination are part of the job. Without them, scientists would not get meaningful results.

A consideration of the personal nature of scientific knowledge is, however, an important component of a discussion of the characteristics of scientists, since scientists, as individuals, have varying personal characteristics such as patience and determination. Polanyi (1978) wrote that as the act of knowing included an appraisal by the individual, factual knowledge was shaped by a personal coefficient. This personal coefficient introduces an element of subjectivity into scientific knowledge. Polanyi asserted that the view that science was an activity that sought to eliminate passionate, personal, human appraisals of theories, or to minimise their effect on knowledge, was in error. Polanyi advanced the forcible conclusion that science could not be conceptualised as a set of objective statements, as the knowledge was entirely derived by observation.

Historical case studies also serve to illustrate Polanyi's concept of personal knowledge. During the Copernican Revolution, by way of example, the theory of Copernicus refuted the evidence of the senses, which presents humans with the conception of the sun, moon and stars as moving around a stationary earth. Copernicus supported the theory of a heliocentric solar system, as, according to Polyani, his criterion of objectivity relied on theoretical knowledge rather than the evidence of the senses.

A further problem with the conceptualisation of science as a body of impersonal knowledge objectively derived by observations is that scientists select evidence in the light of their expectations. Therefore, as Polanyi (1978) asserted, the scientific method or procedures which scientists adopt and the beliefs and values held by scientists are not mutually exclusive. Scientists pursue their work according to what they anticipate should be the case using methods that have previously been successful. Beliefs therefore guide the gathering of scientific evidence and data. Conant (1966) considered that what scientists anticipate or assume to be the case has a significant role in the scientific method. He cited the tacit assumption that the laws of liquid pressure and the density of mercury are not themselves very different at different altitudes, as an example from the field of hydrostatics.

Australian Scientists' Motivation for Doing Science (Item 27)

Scientists' motivation for doing science well is another personal characteristic that varies between individual scientists. Holton (1978) maintained that although the scientists' motivation had become a necessary component of the scientific enterprise, such as the motivation to discover cures and other scientific and technological products that benefited society, this motivation by itself would not be sufficient to sustain the scientific enterprise. Sometimes scientists carry out research according to their particular commitment to the pursuit of knowledge. However, as Ziman (1980) stressed, although one of the goals of research is to satisfy curiosity and a taste for problem solving, the predominant goal of scientists is to add to the body of public knowledge for the benefit of society. The belief of this researcher supports Item 27, Response D, that the main personal motivation of most scientists is solving curious problems for personal knowledge and discovering new ideas and inventing new things that benefit society.

Furthermore, it is significant for this study that the socialisation of scientists tends to produce people who are committed to the central values of science, and are interested and excited by discoveries on the detailed workings of nature. As humans, scientists also work to gain recognition, money and power, like other members of contemporary societies. This desire to obtain recognition leads scientists to publish their work, and as Merton (1957) concluded, the failure to recognise scientific work leads to strong antagonism and controversy. This desire to gain position and money is not, however, as important a motivating force as the desire to gain knowledge, and to benefit society. The claim that scientists are motivated by desire for extrinsic rewards is weakened by the fact that many scientists in senior positions, where the continuation of extrinsic rewards is guaranteed, continue to be highly productive and conform to scientific goals (Hagstrom, 1965).

The effect of the relationship between the work of scientists and political and economic factors in the years since the Second World War, has led to the realisation among most scientists that their work does not end in the laboratory. Rather, scientists have become aware of the need to have a social consciousness that directs them in their quest to discover new ideas and invent new things that benefit society. Scientists have also been brought into much closer contact with the problems that affect the ordinary citizen (Bernal, 1939).

It is written in Chapter 2 that this description of scientists as socially conscious citizens was not supported by Kuhn, who wrote of the prescriptive power of the paradigm. Kuhn (1962) suggested that it was difficult to ensure that the work of scientists served the interests of society as scientists were, to some extent, insulated from society and the demands of everyday life. In Kuhn's view, since scientists worked only for an audience of colleagues, scientists did not have to concentrate attention on problems that urgently needed to be solved for the benefit of society. This insulation from society was, according to Kuhn, greatly enhanced by the nature of the scientists' education. He asserted that undergraduate scientific education was founded upon text books based upon accepted paradigms, rather than upon "the creative scientific literature that made them possible" (Kuhn, 1962, p. 165). Kuhn argued that such a rigid, narrow initiation in the scientific profession was entirely inadequate.

This condemnation, by Kuhn, of hopes for the Baconian science-and-society linkage of science for the relief of human suffering was refuted by Holton's (1978) argument that scientists' social responsibility and social concerns were a consequence of the experiences of the development of the atomic bomb during the Second World War.

Holton contended that evidence of the trend towards social responsibility included honourable institutional inventions and landmarks, which ranged from:

> ..the founding of the Federation of Atomic Scientists and the appeals of Leo Szilard and James Franck in 1945 to the Asilomar Conference on Recombinant DNA research (1975). (Holton, 1978, p. 234)

Thus, scientists are certainly not insulated from society now, if indeed as human beings they ever were, and most scientists are motivated by a desire to serve the interests of society.

The Effect of the Values of Scientists on Science (Item 8)

Item 8 related to the effect of the values of scientists upon science. It began with the suggestion that a scientist's religious views would not make a difference to the scientific discoveries he or she made. In order to address this issue, it is necessary to consider both the influence of scientists as individual humans, and the personal aspect of scientific knowledge.

The implications of the personal aspect of scientific knowledge are that scientists, as individuals, have their own particular value-systems, personal agenda and characteristics, which determine their personal motivation for doing science, as well as the contributions that they make. Scientists, as humans, make moral judgments, as argued by Polanyi (1969), and these judgments direct their actions. They therefore choose different areas in which to work. By way of example, scientists' religious views may influence the discoveries scientists make, as stated in Item 8, Response D, because sometimes religious views affect what scientists do, or what problems they choose to work on.

The effect of scientists' individual, non-scientific beliefs on the direction of science is not elaborated upon by Kuhn, and neither does he provide a real analysis of the social and scientific implications of the issues confronted in scientific research, as Riggs (1992) maintained. Kuhn (1970a) suggested, however, that the act of discovery should be assigned to an individual and to a moment of time, in order to acknowledge the contribution of the context and values of the individual to that scientific discovery. A consequence of Kuhn's work is that the discovery of anomalies to a scientific paradigm is infrequent, since the criteria for choosing problems to be addressed by science are prescribed by the paradigm.

Polyani (1978) suggested that the motivating force for the passing over of contradictions was personal judgment and individual valuing, whereas Kuhn contributed this wavering of discrepancies to the prescriptive power of the paradigm. The imagination of individual scientists may be guided by fidelity to one or more factors or themes such as values (Holton, 1978), and they may also play a major role in the initiation and acceptance of scientific insights. Adherence to these themata may benefit or disadvantage the advancement of science. Religious values may, therefore, make a difference to the scientific discoveries made by scientists.

Individual Scientists and the Scientific Method (Item 11)

The scientific method employed in daily scientific activities is described in traditional science courses as a means of discovering the laws of nature by impartial investigators conducting research in a manner dictated by empirical facts and logic (Riggs, 1992). Moreover, scientific training leads scientists to commit themselves to particular theories and techniques (Hagstrom, 1965). Therefore, most scientists tend to follow the basic scientific method, which is useful in many instances, but it does not ensure results. As suggested in Item 11, Response C, the best scientists also use originality and creativity.

As Hagstrom further suggested, change is necessary for any scientific community to thrive. Scientists must continually change their techniques in response to their discoveries. Moreover as well as possessing the flexibility to respond effectively to change, the best scientists must also possess individual abilities which enable them to use techniques such as the prophetic guesses employed by Rumford (Goldstein and Goldstein, 1978). The great "leaps forward," or major contributions to science, have employed experimental techniques other than those that adhered to the traditional scientific method (Ziman, 1980). These great contributions to knowledge have also required personal traits such as highly developed intelligence, imagination, originality and creativity. Conant (1966, p. xi) supported this view that scientists' personal characteristics such as inspiration and highly-developed intelligence were necessary for great advances in science, when he emphasised his belief that brilliant hypotheses often originated in the minds of scientists by processes he described as an "inspired guess", "intuitive hunch" or a "brilliant flash of imagination".

The scientific method used by scientists does, however, depend upon the paradigm within which the scientist is working and that is not always entirely rational. Albury and Schwartz (1982) agreed when they questioned whether there was a scientific method and concluded that:

> ..the scientific method, if one exists at all, is not a universal process for arriving at the truth but a way of deepening the knowledge available within a particular framework. (Albury and Schwartz, 1982, p. 78)

After using case histories to illustrate the methods of science Conant (1966) emphasised his belief that:

> ..there is no such thing as the scientific method, that there is no single type of conceptual scheme and no set of rules specifying how the next advance will be made through the jungle of facts that are presented by the practical arts on the one hand, and observations of scientists on the other. (Conant, 1966, p. x)

This view supports the statement in Item 11, Response D, that the best scientists are those that use any method that might get favourable results. This includes the use of imagination and creativity.

Under-representation of Females in Science (Item 13)

Item 13 concerned the under-representation of females in science in Australia today. It was designed to gain respondents' views as to the reasons for the greater number of male than female scientists. In order to address this issue, it is necessary to discuss both the ideology of science and the history of the different views and social expectations relating to females' abilities and participation in science in Australia.

Science is ideological, and scientific theories, investigations and findings have been used to justify particular social positions or reinforce the *status quo* in societies. Furthermore, each group in society is subject to pressures and influences that shape their view of the world and affect their opportunities. Inequitable access to education and careers in science and technology for women was contributed to by studies that claimed that women lacked the necessary spatial skills and abilities to perform these jobs as well as men (Albury and Schwartz, 1982). The traditional stereotype held by society has been that men are more capable in science than women, and this prejudice led to fewer women becoming scientists. Women have largely been discouraged from entering the scientific field.

Recent psychological and genetic experimentation evidence has failed to find any evidence relating to differences between the sexes in intelligence that would limit their achievement in courses and careers in science and technology (Linn and Hyde, 1989). Furthermore, Keeves and Kotte (1992) emphasised that sex differences in educational achievement are a result of social or environmental influences, rather than being due to differences in abilities. As a result of the evidence that females are just as able in the study of science as males, there has been a great deal of activity at both the secondary and tertiary levels to encourage girls to study science. This research at the secondary level and gender differences in motivation and achievement in response to STS are discussed in Chapter 9.

Today in Australia, there are more male scientists than female scientists. The main reason for this is written in Item 13, Response F, that until recently, science was thought of as a man's vocation. In addition, most women were expected to work in the home or take on traditional jobs. Today this is changing. Science is becoming a vocation for women, as well as men and women are expected to work in science more and more. Support for this trend in increasing participation by women in careers in science and technology in Australia is provided by women's advisory groups set up by the Federal Government, and by special research programs conducted by educational establishments and government organisations.

Gender Effects on the Outcomes of Science (Items 4 and 20)

Item 4 in the instrument states that there are many more women scientists today than there used to be. Furthermore, this item continues with the assertion that this will result in differences in scientific discoveries which are arrived at, since scientific discoveries made by women will tend to be different from those made by men. Item 20 addresses the issue that a good female scientist would carry out the job basically in the same way as a good male scientist. These issues are considered in this section.

In May 1993, the Women in Science, Engineering and Technology Advisory Group was established in Australia by the Department of the Prime Minister, to provide advice on strategies to be followed in order to improve women's participation in Science, Engineering and Technology (SET) careers and education. The discussion paper on women in science, engineering and technology produced by this advisory group, raised some issues and recommendations in regard to improving the participation of women in these areas in both the public and private sectors. The advisory group established the need to:

(a) celebrate the value of the different viewpoints, perspectives and styles of operation that women bring to SET and recognise the different ways that women contributed to science, engineering and technology in Australia; and

(b) recognise past and present contributions and achievements of women in SET and remove the socially-constructed barriers which limited their present and future contributions and achievements. (Women in Science, Engineering and Technology, 1994, p. 4)

It is significant for this discussion that the group strongly emphasised that:

> ..women in SET-based education, training and employment contribute creativity, imagination and intelligence to the strong SET base of which Australia is justly proud. (Women in Science, Engineering and Technology, 1994, p. 4)

The group cited the need for a Women in Science and Technology Unit to be established and that the group's key tasks should include:

> ..participating in the development and management of a public awareness campaign directed at improving understanding of the nature and effect of barriers to women's full participation in SET-based education, training and employment caused by gender harassment and other types of exclusion behaviour. (Women in Science, Engineering and Technology Advisory Group, 1994, p. 8)

By way of contrast, a study of female engineering students at the University of Adelaide in 1995 indicated that being female in a male-dominated environment was not an issue, as females felt fairly comfortable in this environment (Copeland, 1995). The students said that there were many instances of "put-downs" and sexual harassment by both male students and staff, but that they felt confident to deal with this. The other conclusion from this investigation which is significant for this study is that the female engineering students had to withstand considerable social, peer group and family pressure in regard to their decisions to study engineering (Copeland, 1995).

This group of female students asserted that females pay much greater attention to the social consequences of their work than do males. Women therefore do science somewhat differently to men, as they are interested in the implications of their work as well as the physical end product. They could make somewhat different discoveries since, as argued in Question 4, Response H, by nature or by upbringing, females have different values, viewpoints, perspectives, or characteristics, such as sensitivity toward consequences. In the report by the Australian Women in Science, Engineering and Technology Advisory Group, it was considered important to value the different viewpoints, perspectives and styles of operation that women brought to science and technology, and recognise better the different ways that women contributed to science, engineering and technology in Australia.

Since women have different viewpoints concerning learning and investigation in science, they relate much more positively to science that is taught and practised from the perspective of social responsibility. This consideration of social responsibility in science by females culminated in the recommendation that resulted from a 1995 study of women's experiences of science and technology at The Levels Campus of the University of South Australia that:

> ..a subject such as Science, Technology and Society, which includes the examination of social issues such as gender and culture, be introduced into the curriculum at The Levels. (Lintern, 1995, p. 29)

This assertion was further supported in an Australian report on engendering technology at the University of Technology, Sydney (Taylor and Huckstep, 1992). This report was founded upon the belief that technology does not shape the future, people do. It was therefore considered to be important for women to participate in decision-making with regard to alternatives to the use of science and technology for the solution of social problems.

Scientists' education and training within the guidelines of the accepted paradigm have a significant effect on the way scientists do science. As a consequence, as argued in Item 20, Response F, when doing science or technology, a good female scientist would carry out the job basically in the same way as a good male scientist. Any differences in the way scientists do science are due to personality differences between individuals, and such differences have little to do with being male or female.

Summary

This chapter has discussed one of the two ways in which the scaling of the instrument used in this Australian study was validated. During this review of the literature published by the experts, items within each of the three domains (*Society*; *Science*; *Scientists*) of the instrument, have been addressed from three theoretical perspectives:

(a) the views that guided the authors in the development of the original VOSTS instrument,

(b) philosophy of science, and

(c) philosophical and sociological foundations of STS.

In this chapter, the views of eminent philosophers and sociologists of science have been used to discuss the STS issues considered in the items used in the scales. Theoretical positions within the philosophy of science, as well as the positions of the authors of the original VOSTS instrument have been considered. In addition, case studies and examples of particular technologies that have been applied in an attempt to solve social problems, together with details of the lives and discoveries of relevant scientists, have been discussed to support the scaling of the questionnaire.

The effects of values, politics and economics on the development and use of science and technology in society, in terms of the influence of the military, governments, religions, educational establishments and special interest groups on science and technology have been discussed. Subjectivity in science may result from the interaction of science and technology with social institutions, since people in these institutions may have vested interests. These vested interests and values may sometimes serve to direct the development and use of science and technology in ways that serve the particular interests of these social groups, rather than for the good of society as a whole.

In Australia, research organisations such as the CSIRO and the ARC have been set up to encourage and coordinate research which contributes to social well-being and economic growth. These organisations contribute to the control of Australian science and technology through the allocation of funding. It is important that governments, which may have vested interests, do not have complete control over science and technology. In addition, it is also important for research in science and technology that might be useful for the Australian society to be well controlled and coordinated. At the same time, respect for the creativity and intellectual integrity of scientists should lead to scientists being provided with sufficient autonomy to enable them to use their creativity to perform successful science. Science and technology can make a significant contribution to the solution of practical problems in everyday life and the well-being of the nation. Science and technology influence the everyday thinking of members of modern societies, and almost every aspect of the lives of citizens in developed societies has in some way been researched by science and technology.

The experience of the development of the atomic bomb in the Second World War demonstrates that scientists and government agencies, as well as other informed members of society should together decide what is investigated by scientists. This requires that high school science is taught with the inclusion of the discussion of STS issues. The values of scientists and individuals in society, such as those in special interest groups, have a substantial influence on the advance of science and technology in the Australian society.

Innovations in science and technology have the potential for negative as well as positive effects on society. In this chapter, a discussion of the development of the atomic bomb has highlighted the social responsibility of scientists, as well as the unwanted or undesirable effects caused by the application of science and technology. In developing countries, the problem with the use of science and technology is that they are capital-intensive. The people in these countries do not have either the capital or the skills necessary for the effective use of science and technology to improve their economies.

There are also moral and ethical implications of the use of science and technology in society. These issues need to be debated when policy decisions on the use of science and technology in society are formulated. This need for social debate in regard to the use of science and technology in society is further reinforced by the fact that science and technology are so vital to establishing the social fabric of present societies that they even assist in the formulation of verdicts of guilt or innocence during legal decision-making.

Science is value-laden, since as human beings, scientists' values affect the areas of research they choose, and the observations they make during this research. Thus, since scientists cannot always be completely objective in their work, there may be an element of subjectivity in science. For scientists' work to serve the best interests of society, it is important that scientists are socially conscious. It has been suggested that this is especially the case in the years since the Second World War, since this was when the atomic bomb was developed and used. Important aspects of the effects of the characteristics of scientists on the development of science and technology in society, which have been discussed in this chapter, range from Australian scientists' motivation for doing science to gender effects on the outcomes of science.

A scientist's personal motivation for doing science depends upon the personality and motivation of the individual. The goals of most scientists are to gain knowledge and to benefit society. By way of example, a scientist's religious views make some difference to his or her contribution to science, since these views could influence the discoveries the scientist makes, by determining the problems chosen for investigation. Although scientists are trained to use the traditional scientific method, some of the major scientific advances have not used traditional methods. Moreover, the hypotheses for the studies, which led to these advances, have often originated from "intuitive hunches" or "brilliant flashes of imagination".

Traditionally there have been fewer female scientists than male scientists in Australia, because the traditional view has been that men were more capable in science than women. This situation has changed greatly, since it is now believed by many people that a good female scientist carries out the job in basically the same way as a good male scientist. Any differences in the methods used by male and female scientists are due to personality differences between individuals. These differences have nothing to do with being male or female. This idea has gained far greater acceptance than the previous belief that males had superior ability in science than females.

After the validation of the scales in this chapter, by discussion of the experts' theoretical positions on the philosophical and sociological foundations of the issues of STS, the responses of students, teachers and scientists can be quantified with greater confidence, so that it is possible to examine the factors influencing these respondent's views on STS. The responses to the items in the instrument, which was used during this Australian study, were scaled by the researcher on the basis of both the STS literature, which has been discussed in this chapter, and the researcher's judgment. The other method of validation of the scales was provided by a comparison of the original scales with the views of the experts, since they provided an independent scaling of the instrument. The development of the scaled items is the topic of the next chapter. In the following chapter, the comparison of the researcher's scaling of the VOSTS items with the scaling provided by the experts is discussed. The comparison of the views of students, teachers and scientists, on the basis of this scaling, is discussed in Chapter 12.

7

Measuring Students' Views on STS: The Development of Scales

One of the aims of this Australian study was to develop a master scale to measure views on STS. Thus, it was necessary to assign scores to the alternative responses or views for the statements comprising the scales used in this study. The scores or codes of the final scales were based upon preliminary analysis and the researcher's judgment developed from a review of the literature (see Chapter 6), and the validation study, which used the opinions of the experts to confirm the numerical codes assigned to the responses. Furthermore, it was also important to test the items in the scales to see whether the model of a unidimensional scale fitted the data. As a consequence, it was possible to show that by using these codes, all items finally employed fitted their particular scale very well. The development of the scales, the calibration of the scales and the determination of how well the data from the respondents fit the Rasch scale are discussed in this chapter. The subsequent use of the scales and their internal consistency and meaning are also described. Moreover, the validation of the scales by using the opinions of the experts is discussed. For convenience and to avoid repetition, the views, beliefs and attitudes of students, which are investigated in this study, are referred to as views, with recognition that no attempt is made to assess knowledge and understandings of science and STS issues or of values towards science and STS issues.

Initial Tasks for the Construction of Scales

Oppenheim (1992) stressed very strongly that a great deal of careful thought and consideration, and repeated conceptualisations, were necessary to produce effective attitude scales. Furthermore, he suggested that after trialing the item pool in a pilot study, a large number of attitude statements (the item pool) should be analysed and submitted to a scaling procedure. The resultant scales, each of which consisted of a smaller number of statements than in the original item pool, could be used to allocate a numerical score for each respondent. A procedure similar to the one described by Oppenheim for the development of attitude scales was used in this study, although the study sought to construct what may be best considered as view or descriptive scales (Morgenstern and Keeves, 1997).

The Original VOSTS Instrument

The scales used for this Australian study were constructed from the Views on Science, Technology, Society (VOSTS) instrument (Aikenhead, Fleming and Ryan, 1987), which was developed empirically over a six-year period using the viewpoints of senior secondary students in Canada. The VOSTS instrument was designed to overcome ambiguity in students' perceptions of issues concerning the epistemology and sociology of science. Aikenhead and Ryan (1992) argued that the assumption that students and researchers received and interpreted test statements in the same way was incorrect. These authors stressed that the validity of other instruments was undermined by ambiguity, but this problem had been diminished effectively in the VOSTS instrument by the empirical derivation of the multiple-choice items.

Aikenhead and Ryan (1992) contended that the shift in emphasis of their instrument from scales, which were derived from researcher-based viewpoints, to the VOSTS instrument, had implications when the issue of the instrument's validity was addressed. The authors stressed that the validity of the VOSTS items lay in the trust that subsequent researchers placed in the processes, which were used to compile the items. Paragraph responses from students, which reflected the students' underlying views, and follow-up interviews, were used to develop the multiple-choice items. Aikenhead and Ryan believed that the processes used to write the VOSTS items from students' perspectives conferred an inherent validity to these items. They believed that it was, therefore, not appropriate to speak in the traditional sense about the validity of VOSTS items. Moreover, Aikenhead and Ryan (1992) concluded that the field of item response theory had not yet developed the mathematical procedure that could analyse responses to VOSTS items (Aikenhead and Ryan, 1992, p. 488).

It must be argued, nevertheless, that Aikenhead and Ryan were apparently unaware of the ways in which the partial credit model of item response theory might be employed to calibrate the students' responses to the items that these researchers had developed, provided the items and the assigned code values were consistent with the requirement of unidimensionality associated with the scale domain that they had defined. This present study therefore challenged Aikenhead and Ryan's contention in order to measure students' views and to compare their views with those of their teachers and professional scientists in a systematic way. In addition, the study sought to show that there was internal consistency within both the categories of items that Aikenhead and Ryan assembled, and within the underlying views of students in relation to STS issues, that provided strong meaning to their responses. Thus, the validation of the instrument was a necessary and critical component of this use of scale scores to compare the views of students, teachers and scientists.

The Choice of a Scoring Procedure for the VOSTS Instrument

For the purposes of the study reported in this work the view of Aikenhead and Ryan (1992) that it was not yet possible to analyse responses to the VOSTS instrument in a quantitative manner, was considered to be erroneous, and the study sought to establish that item response theory could be used in the analysis of the VOSTS items. The further analysis of items used statistical procedures that are discussed in Chapter 5.

An American study (Rubba, Bradford and Harkness, 1996), which began at a similar time to this Australian study, also took up the challenge to develop a scoring procedure that would allow for comparisons and hypthesis testing using inferential statistics with VOSTS data. During the development of their procedure for scoring the VOSTS items, the American researchers charged a panel of five experts to provide an independent classification on a three-point scale of the multiple-choice responses for each of the items in the VOSTS instrument. However, the scale that they developed remained fully dependent on the items they employed and the judgments of the experts that they chose to calibrate the items.

In this present study, seven experts from the Australasian Association for the History, Philosophy and Social Studies of Science provided their individual scores for the VOSTS items on a five-point scale, with an omitted or non-specific response scored zero. This was considered to provide evidence for an appropriate validation of the scores that were allocated to the multiple-choice responses associated with items in the VOSTS instrument. The scores had previously been assigned according to the researcher's judgment based on a review of the literature. A similar approach to validation of test items, which involved the collection and use of reviewers' judgmental data, was described by Hambleton and Rogers (1991). Rubba, Bradford and Harkness (1996), however, did not provide a detailed account of their reasons for using experts to classify the multiple-choice responses. Furthermore, it is significant that in a similar way to this Australian study, the codes or scores, which the American experts assigned to the responses, displayed considerable disagreement in some cases.

There are many marked differences between the Australian and American studies, including the fact that the inferential statistical procedures used in the studies differed substantially. A much deeper analysis was conducted using the Australian data, in so far as the initial codes assigned to responses by the investigator were derived from theoretical analysis of published accounts and discussions of the nature of the relationships between science, technology and society. In addition, unlike in the American study, the Australian model was tested for unidimensionality by analysis of fit of the student data from the pilot study. Moreover this present study sought to develop an interval scale on which the students' responses could be measured with a specified probability of response (in this case p=0.5) between the underlying view of a respondent and the chosen response to an alternative within each particular item.

This study did not employ, as had Rubba, Bradford and Harkness (1996) a rubbery, or elastic, set of ratings that provided, at best an ordinal scale, without any checking for the unidimensionality of responses. Furthermore, the Australian study constructed a scale that is independent of the sample of persons used in calibration and independent of the particular items employed in the questionnaire. This property of the three scales would permit items to be added to or removed from the scales without changing the metric properties of the scales.

The Selection of Items

In this section the selection of items is discussed. The selection of items that constituted the instrument was the second step in the development of the scales for this study.

Procedures for the Selection of Items

First, after reading and considering Aikenhead and Ryan's VOSTS instrument carefully, the 45 items that comprised the trial instrument were chosen. As discussed in Chapter 1, the items were chosen from four of the nine domains that were in the original VOSTS instrument, although after the pilot study these domains were reduced to three, which were:

1) the influence of society on science and technology *(Society);*
2) the influence of science and technology on society; (*Science*); and
3) the characteristics of scientists (*Scientists*).

Considerations, which guided the choice of items to be included in the final instrument in this present study, were clarity, ease of understanding, and whether the items were concerned with an issue that had not been addressed by another item, which had been selected previously. Thus the number of items was reduced from 45 to 27 after the trial. Various processes were employed in order to select effective items to form a balanced sample for each of the three scales. The characteristics of good items for inclusion were identified by consideration of the literature relating to the construction of effective items for attitude and descriptive scales. In addition item analysis and Rasch scaling procedures were used to identify items that could be discarded in order to reduce the length of the instrument and to ensure that it did not occupy more than one class period. The item analysis and scaling procedures are described in the sections that follow.

Items Selected for the Final Instrument

One of the reasons for the rejection of items from the original instrument used in the pilot study was that the pilot survey showed that students required far greater time than the length of a regular lesson (40-50 minutes) to respond to the instrument composed of 45 items. However students were able to complete the final, revised instrument of 27 items in a regular class period. This facilitated the administration of the final instrument.

In addition to item response theory as a basis for discarding some of the items from the trial study instrument, further items were rejected on the basis of insufficient clarity of the items. The goal in developing instruments comprising items for assessing attitudes and views is that they are clear and unambiguous to the reader (Thorndike, 1982). The practices that have been suggested for the promotion of clarity include:

> 1) Limiting each statement to a single idea by avoiding complex or double-barrelled statements;
> 2) Using simple language to express the idea accurately;
> 3) Avoiding negative statements, particularly when the combination of the statement and response would form a double negative;
> 4) Ensuring that each statement represents a statement of attitude or belief; and
> 5) Ensuring that vague modifiers such as strongly, occasionally or often are used sparingly, if at all. (Thorndike, 1982, p. 50)

In the VOSTS instrument, the use of simple language to express the ideas accurately in order to facilitate the respondent's understanding of the items was accomplished by the empirical basis for the development of the original instrument in Canada (Aikenhead, Fleming and Ryan, 1987). However, after the pilot study, some of the items were rejected on the evidence of insufficient clarity relating to the five unsatisfactory practices listed above. The evidence came from the inconsistencies in the students' responses, as well as from a careful examination of the items and the statements contained in them.

Both the selection and arrangement of items in the final scaled instrument used in this present study were aimed to discourage students from forming patterns of responses. It was considered important to discourage students from responding to items in a way that was primed by previous items, which students considered to be similar to the later question. Hence, it should be noted that not all items, which were eliminated, were unsatisfactory items, since some of the items were eliminated largely on the grounds of duplication.

Models of Measurement

For the purposes of this study, the form of statistical analysis used to establish unidimensionality and consequent interval scale measurement was the Rasch partial credit model (Rasch, 1960) based on the item response theory analysis of the students' levels of performance in relation to the items of the instrument. This technique is an example of a latent trait model, which is a theoretical approach to educational measurement for instrument items in which two or more ordered levels of outcome are defined (Masters, 1988). These models have considerable advantages when compared with the classical measurement models. The characteristics and advantages of these models are discussed below, after a discussion of the limitations of classical measurement models.

Limitations of Classical Measurement Models

It was considered important to use in this study an alternative to the classical measurement models, such as that subsequently found to be used by Rubba and his colleagues, since limitations of these classical measurement models would make it difficult to obtain valid measurement of the STS views of respondents. The limitations of the classical measurement models include:

1) the examinee characteristics and the test characteristics could not be separated, or interpreted independently of the other;
2) item discrimination, test score reliability and validity were defined in terms of a particular group of respondents, hence it was difficult to compare responses to items whose characteristics were derived from very different groups of respondents; and
3) consideration of how respondents replied to a given item was not provided, therefore it was not possible to examine how a particular respondent might be expected to score on a particular item (Hambleton, Swaminathan and Rogers, 1991).

Classical test theory is based on a measurement model in which each individual has an unobservable quality or true score that cannot be measured directly. In this model, the scores assigned depend upon the difficulty level of the items used (Weiss and Yoes, 1991). These classical measurement models provide less-than-ideal solutions to problems involved in designing measuring instruments and identifying biased items. Consequently, psychometricians have recently sought alternative models of measurement.

The Latent Trait Theory

The measurement processes in this Australian study employed a scaling model in which scale values are assigned to both the items and the respondents. As Keeves (1992b) wrote on the latent trait theory, it is a requirement that there is a common underlying trait of performance for both respondents and the items that are used. The items and the respondents are located at levels along a scale defined by the latent trait. In this study, the latent trait is the strength and coherence of students' views towards issues resulting from the relationship between science, technology and society. The position of an individual respondent on the latent trait scale is that level at which the respondent would answer, with a specified degree of probability, an item located at that level on the scale (Keeves, 1992b). In this scaling model used in the present study, the respondents depend on the strength and coherence of their underlying views towards STS to respond to the items in a favourable manner.

Thus in this analysis using item response theory, item characteristic curves relate the probability of success on each item to the strength and coherence of respondents' underlying STS views. Moreover, for consistent and meaningful measurement, it is necessary for all items to have item characteristic curves of very similar slopes. This requirement is consistent with the need for a unidimensional scale of measurement.

Partial Credit Model

The model of measurement used in this study is the partial credit model of item response theory. The two basic postulates of item response theory are:

(a) the performance of an examinee on items can be predicted by factors called latent traits, or abilities; and

(b) the relationship between item performance and the set of underlying traits can be described as a monotonically increasing curve called an item characteristic curve. (Hambleton, Swaminathan and Rogers, 1991; Weiss and Yoes, 1991)

This item characteristic curve relates the probability of success on an item to the ability measured by the test and the characteristics of the item (Hambleton, Swaminathan and Rogers, 1991). The particular item response model used in this study is the Rasch partial credit model. The Rasch model is a one-parameter logistic model that has superior measurement properties. Since the item characteristic curve is a one-parameter logistic function, the items employed under this model must be specifically chosen to meet the requirement of parallelism to the item characteristic curve (Hambleton and Swaminathan, 1985). The advantage of item response theory over classical test theory is that the scores provided are not dependent on the specific set of items administered or the specific group of persons used in calibration (Weiss and Yoes, 1991).

In order to use the Rasch partial credit model, it is necessary to assume that the items occupy a space along the latent trait continuum that is consistent across both the entire group of students and the set of items being sampled (Keeves, 1988). Thus the partial credit model is a measurement model, since it provides a probabilistic connection between the categories of observed outcome on an item and the respondents' location on a latent trait of developing views. This probabilistic connection provides a basis for constructing measures of the respondent's views from a set of items with multiple outcome categories (Masters, 1988). As stated in Chapter 5, Aikenhead hadn't realised that item response theory had advanced to the point of encompassing a multitude of student responses. Hence this study, which uses item response theory to establish the consistency of the scaling of the VOSTS items developed by Aikenhead and his colleagues is a significant advance in educational research in this area.

In order to use this model, the item data and the respondents' data must fit the model well (Hambleton and Swaminathan, 1985). Thus the items in the final instrument used in this study had to be selected through the determination of the degree of fit of the item to the model. The selection of suitable items ensured that the item discriminated effectively, and provided specified levels of the respondents' views on the scale of the latent attribute assessing the strength and coherence of the respondents' views towards STS. Ambiguous or non-discriminating items had to be discarded, as did items that provided redundant information.

Item response data are examined commonly to determine item discrimination indices in addition to item difficulty levels (Hambleton and Rogers, 1991). In this Australian study, analysis of fit of the item to the required characteristic curves also guided the selection of items for the final scales using the data collected during the pilot study. If the infit mean square value was too low, the slope of the item curve was too steep. Hence, if an item was found to be too effective in discrimination, it had to be excluded from the final scales because it provided redundant information. By way of contrast, if the infit mean square value was too high and the slope was too flat, the item was not sufficiently effective in discrimination. As a consequence, such items also had to be rejected. The suitable items had to have an infit mean square value of approximately 1, and by convention only items in the range between 0.83 and 1.20 are employed under the partial credit model (Adams and Masters, personal communication, 1995).

Issues of Consistency and Validity

The first step in scaling the VOSTS items was determining response values, or which of the responses for each item were allocated the codes of 4, 3, 2, 1, or 0. This initial scaling was performed after consideration of the literature (see Chapter 6). It was then important to determine the consistency of the scale using item response theory, and to establish the validity of the scale using the views of a panel of experts.

With the use of the QUEST program (Adams and Khoo, 1993), the values for strength and coherence of the views of the respondents corresponding to each score level were determined and estimates were obtained for the difficulty parameters of each of the items in the scales. It was then possible to determine how well the model fitted the data. This was necessary, since as Wright (1988) has stressed, if the model did not fit the data, then it could not be used to calibrate items or to measure persons. Thus, Wright has argued it is necessary in order to achieve measurement to examine the validity of both item response patterns, and person response patterns, by evaluating the fit between the model and the data.

Response Validation by Analysis of Fit

The alternative codes for the statements comprising the items varied in their positions along the graph of the latent trait, with the high codes at the top of the graph and the lower codes towards the bottom. The map also showed the position of the response groups that were formed on the same scale. It was expected that equivalent codes for each item should all be located at a similar threshold level along the y-axis. Thus, if the codes for an item differed substantially in position from that of the equivalent codes for the other items, either the item was rejected, or the assigned codes were reconsidered and adjusted. The scales used in the study were, in this way, calibrated for use. If the fit of an item to the scale was acceptable, the item was considered to be consistent with the underlying scale.

Wright (1988) maintained that the extent to which the data on each item were consistent with the latent variable implied by the collection of items in a instrument provided a check on the internal validity of the scales. It might be argued, however, that this was a check on the consistency of the scales, rather than the internal validity of the scales in terms of how faithfully they measured what they were supposed to. However, it must be noted that a measure of the internal consistency of a scale provides an upper bound for any measure of the internal validity of that scale. The state of being consistent has been defined as being "compatible, not contradictory, constant to same principles" (Sykes, 1976, p. 216). The consistency may thus be determined by examining the data gathered during a pilot study using a group of respondents with similar characteristics to those for whom the scales were intended (Hambleton and Zaal, 1991). Consequently, in this study, the consistencies of the items and students' responses were initially established using student data from the pilot study before the scales were employed to measure the views of senior secondary science students in the 29 South Australian schools and colleges that were visited during the study. The internal consistency was therefore demonstrated, in the first instance, by how well the data fitted the Rasch scale. In this present study, the analysis also demonstrated the degree to which the items satisfied the requirement of unidimensionality, which must be seen to be an aspect of the validity of the scale.

Furthermore, invariance of item and ability parameters, which only holds when the data fit the model well, is an indispensable part of item response theory, since it enables applications of the theory in such investigations as those of item bias (Hambleton, Swaminathan and Rogers, 1991). Therefore, it was very important to determine whether the results obtained for this study fitted the partial credit model well. Fortunately, the fit of the student data to the model was so good that Masters, the developer of the partial credit model, after an examination of the results, agreed that the three master scales were well-supported, and the researcher could proceed confidently with the data analysis and discussion.

Internal Consistency, Validity and Reliability in Item Response Theory

In evaluating the instrument used in this Australian study, it was important to address the issues of its internal consistency and reliability as well as its validity, in order to determine the generalisability of the scores allocated to respondents, and the range of measurements that could be made from the scores. After the internal consistency of the items was examined using Rasch scaling the difference between internal consistency and validity was considered. One conception of validity was how faithfully the set of items in an instrument corresponded to that attribute in which the researchers were interested (Thorndike, 1982; Hambleton and Rogers, 1991). The scores were valid if, in fact, a test measured what it purported to measure, since validity was " a judgment based on evidence about the appropriateness of inferences drawn from test scores" (Cohen et al., 1988, p. 123).

When a test or educational instrument was designed to measure a latent attribute (in this case the strength and coherence of respondents' views on STS), its construct validity was concerned with how well it measured the attribute it was designed to measure (Thorndike, 1982). Thorndike also contended that the "theory" of the attribute or construct suggested kinds of evidence that should be relevant for assessing how well the instrument elicited the construct. In the context of this study it was, therefore, important to ascertain how meaningfully a high score for responding to the issues addressed in the scales represented the strength and coherence of respondents' views, beliefs and attitudes in relation to STS. Consequently the construct validity was established by a panel of experts in order to check the scaling of the instrument, and a further method of validation in terms of the underlying theory of the instrument was provided by a review of the literature.

The reliability of the instrument was also considered, since the concepts of reliability and internal consistency have been related by Cohen et al. (1988) within classical test theory. These authors suggested that a good instrument was reliable, with the criterion of reliability being related to the internal consistency of the measuring tool. It was concluded that this concept of reliability defined in this way was not relevant for the present study, in which the internal consistency of the instrument was assessed using item response theory. Hambleton and Zaal (1991) supported this conclusion when they wrote that the concept of internal consistency in item response theory was very different from that of classical test theory. As a consequence, this present study abandoned the conventional concept of reliability, which depended heavily upon the sample used. Furthermore, this study did not address the conventional concept of validity based on reliability, since internal validity and internal consistency were established largely by how well the data fitted the Rasch scale.

Validation of the Scales by the Experts

In addition to the review of the literature discussed in Chapter 6, seven experts contributed to a study of validation for the scales, by each providing an independent scaling of the individual statements for each item of the instrument on a four-point scale. These values were then compiled to reach an overall consensus on the valid scores for each of the statements employed in the scales. The major data collection of the study could be embarked upon with confidence once this further test of validity of the items had been established.

This method of establishing the validity of the items, by using data provided by a panel of experts, was used in a previous study by Bradford and Harkness (1996). The scaling used in this present study is more meaningful than in the 1996 study, due to the use of item response theory. Moreover, asking a panel of experts to determine the content validity of test items was discussed by Cohen et al., 1988. It was suggested that after the panelists' responses were collected they should be pooled, and the number of people selecting each response counted. An example discussed by Cohen et al. of this type of validation of an instrument to measure attitudes was Thurstone and Chave's (1929) validation of a test to measure attitudes towards the church.

Tables 7.1 and 7.2 show the validity of the final scores for the *Society, Science* and *Scientists* scales by comparison between the experts' scores and the researcher's scores. After the experts' scores were collected, the items were separated by scale, and three tables were prepared, with the items in numerical order. The agreement between the experts' scores and the final scores used in this present study was examined. First, the experts' scores were pooled and the experts' mean scores for the responses for each item were calculated. The experts' mean scores were then ranked. Subsequently, overall experts' scores were determined according to this ranking.

Table 7.1 Validation of response scores using the ratings of the experts - Scale: Society

Item No 3									
Response Category	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Expert mean scores	2.00	2.43	3.14	3.00	1.43	1.86	0	0	0
Expert ranks	4	3	1	2	6	5	7	7	7
Expert scores	2	3	4	4	1	2	0	0	0
Scale scores	2	2	3	4	1	1	0	0	0
χ^2 7 = 4.0	p [a]= 0.14			R C[b] = 0.94		% ag [c]= 0.57			

a: probability value; b: reliability coefficient; c: percentage agreement

Secondly, the 'a' level of agreement, or significance of any differences between the researcher's scale scores and overall experts' scores was determined using χ^2 values and percentage agreement. For each item, the χ^2 value and its probability were calculated using the reliability analysis routine in SPSS with the Friedman ANOVA option, with zero forming only one category.

Table 7.2 Summary statistics for the validation of response scores using the ratings of the experts for Society, Science and Scientists Scales

Item No	χ^2	p [a]	R C [b]	% ag [c]
Society Scale				
3	$\chi^2_7 = 4.0$	0.14	0.94	0.57
5	$\chi^2_9 = 3.0$	0.39	0.92	0.44
9	Zero		1.00	1.00
12	$\chi^2_9 = 3.2$	0.20	0.93	0.67
15	Zero		0.98	0.86
19	Zero		1.00	1.00
21	$\chi^2_6 = 0.0$	1.0	0.93	0.50
23	Zero		1.00	0.67
25	Zero		1.00	0.33
Science Scale				
1	$\chi^2_8 = 4.4$	0.35	0.85	0.38
2	$\chi^2_6 = 3.2$	0.16	0.97	0.67
7	Zero		0.98	0.86
10	$\chi^2_9 = 2.0$	0.16	0.97	0.78
14	Zero		1.00	1.00
16	$\chi^2_8 = 2.0$	0.37	0.93	0.63
17	Zero		1.00	1.00
22	Zero		1.00	1.00
24	Zero		0.95	0.71
26	Zero		0.89	0.43
Scientists Scale				
4	Zero		0.99	0.90
6	Zero		0.95	0.90
8	Zero		0.95	0.60
11	$\chi^2_9 = 3.2$	0.20	0.94	0.50
13	$\chi^2_9 = 2.0$	0.16	0.97	0.78
18	$\chi^2_7 = 5.8$	0.21	0.89	0.28
20	$\chi^2_{10} = 5.3$	0.38	0.89	0.40
27	$\chi^2_9 = 4.4$	0.22	0.94	0.56

a: probability value; b: reliability coefficient; c: percentage agreement

The reliability coefficient was obtained as a Cronbach α coefficient also from the SPSS program. The percentage agreement was calculated for each item by dividing the number of responses where there was complete agreement between the researcher's scale scores and the experts' scale scores by the total number of responses for the item. For Item 3, by way of example, the percentage agreement (0.57) is calculated by dividing the number of responses, which are in agreement (4) by the total number of responses (7). When there is a very high level of agreement, the reliability coefficient goes to one, and the per cent agreement goes to one.

The coefficients of concordance were not used to indicate the significance of any difference between the scores and the experts' score, since they could not be used for all cases. However, the method of validation using χ^2 values, reliability coefficients and percentage agreement showed that while the experts' scores and those of the researcher were not in complete agreement, there was sufficient agreement to indicate that the scoring employed was valid in so far as it was in agreement with the scoring provided by the experts.

The Calibration of the Scales

During this study, analysis of the fit of the model to the data was conducted by using the Rasch model to place the people and the items on the same unidimensional interval scale. The fit between the model and the data was established primarily by using the item infit mean square values. This analysis also examined the item analysis results for observed responses, item difficulty level estimates or threshold values and maps of respondents and items for each scale. Hence, it is important at this stage to describe, in some detail, the techniques of analysis that were used.

In this analysis it was necessary to consider the consistency of responses, and consequently, the ability or performance levels of the respondents. Hambleton and Swaminathan (1985) suggested that some people perform a task more consistently than others, and that consistency varies with ability or performance levels. They argued that:

> ..the performance of high-ability examinees on several parallel forms of a test might be expected to be more consistent than the performance of medium-ability examinees. (Hambleton and Swaminathan, 1985, p. 3)

In the light of this claim it is interesting to note that the responses of the 1278 Year 12 students in this study were found to be highly consistent. A previous study of students' beliefs about scientific concepts also showed that there was consistency in the nature of the beliefs held by differing groups of students (Gunstone, 1987). Abilities have been considered synonymous with traits or competencies since the term ability is a label that is used to designate the trait or characteristic that a test measures (Hambleton and Swaminathan, 1985, p. 54).

The probability of a correct response depends, in item response theory, on both the examinee's ability or performance level and on the difficulty parameter of the item, which is its difficulty level or threshold. In this study, both the respondents' ability and the item threshold parameters were initially unknown. After the data had been collected and entered, the ability parameters of respondents and the Thurstone threshold values for the response categories for each item and the fit parameters of the item and the persons were estimated by using the QUEST computer program (Adams and Khoo, 1993). The parameters that were associated with the theoretical item response curve were estimated using a maximum likelihood procedure. The use of a logarithmic transformation simplified the computation and the values that maximised the function were found using the QUEST computer program (Adams and Khoo, 1993).

A minor disadvantage of this procedure was that ability or performance estimates associated with perfect and zero scores did not provide information for the analysis. There were no zero scores in the sample, so these did not need to be considered. It was necessary, nevertheless to exclude those students obtaining perfect scores in the main analysis and subsequently to calculate the item parameter estimates for their perfect scores. Moreover, the item response theory operates on the assumption that traits or abilities can be predicted from performance on a test, or instrument, such as the one used in this study. The ability or performance scale is transformed through Rasch scaling with the condition that the probability of a correct response equals the probability of an incorrect response. The units on this scale are logits (Hambleton and Swaminathan, 1985, p.53). In the section that follows, a detailed account is given of the information that is provided in the QUEST program for the analysis of a particular item.

Item Analysis and Response Values

Table 7.3 shows the Item Analysis results for observed responses for students for Item 3 of the *Society* scale. There are nine possible multiple-choice responses for this item, and ten categories of response: 0,1,2,3,4,5,6,7,8, and 9 if the omitted response is also considered. The QUEST computer program (Adams and Khoo, 1993) was used for item analysis in this study. The first task in the development of a scoring procedure for the VOSTS instrument was the recoding from the original alphabetical or numerical coding system for the responses for each item to item characteristic scores, between zero and four, which were allocated to the responses for particular items. Hence, these numerical categories of response were recoded to 0,2,2,3,4,1,1,0,0, and 0 once scores were allocated to each response. This is a five-point scale, since scores from 0-4 were used. The initial scores were assigned by the researcher based on an understanding of STS theoretical positions. Those response categories most consistent with the 'ideal' STS position were assigned a score of 4 and those least consistent with the 'ideal' STS position were assigned a score of 0, with intermediate scores assigned accordingly. In the item analysis results for observed responses for students on the *Society* scale, information for each of the categories on the print-out includes: the counts, percentages, point-biserial correlations, p-values, mean ability levels, step labels, Thurstone thresholds and errors.

Table 7.3 Item Analysis results for observed responses: students on Item 3 on Society Scale (N = 1278; L = 9)

Item 3 (Disca = 0.47) Infit MNSQb = 1.06

Categ[c]	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Score Code	0	2	2	3	4	1	1	0	0	0
Counts[d]	3	203	109	147	382	277	83	14	32	28
Percent[e]	0.2	15.9	8.5	11.5	29.9	21.7	6.5	1.1	2.5	2.2
Pt-Biser[f]	-0.02	0.01	-0.07	0.07	0.37	-0.13	-0.17	-0.21	-0.23	0.15
p-value[g]	0.221	0.425	0.005	0.004	0.000	0.000	0.000	0.000	0.000	0.000
Mean Ability[h]	0.02	0.23	0.11	0.35	0.53	0.10	-0.10	-0.84	-0.61	0.30
Step Labels		1	2	3	4					
Thres[i]		-1.75	-0.13	0.41	0.73					
Error		0.16	0.09	0.09	0.10					

a: discrimination index; b: infit mean square; c: response category d: number of respondents;
e: percentage of respondents; f: point-biserial correlations; g: probability that the point biserial correlations are significantly different from zero; h: mean ability level for respondents;
i: Thurstone thresholds: difficulty levels

In a way that was similar for all of the other items, the results for the observed responses for Item 3 demanded very careful examination during this stage of the study. A substantial amount of very important information was provided by the distractors or alternative response categories that Aikenhead developed, and it was important to use this information, rather than to ignore it. This item analysis information showed the results for observed responses, and how students responded to each of the response categories for each item.

The point-biserial values (point-biserial correlations) provide information on the discrimination for each response category (Hambleton and Swaminathan, 1985). For Item 3 (see Table 7.3), the point-biserials related well with the mean ability or performance values for students responding to this response category.

By way of example, response Category 4, which drew 382 (29.9%) of the students had been assigned the highest score of four and had the highest mean ability level for respondents of 0.53 and a point-biserial correlation of 0.37. For the next highest score of three for Category 3, the mean ability level was 0.35, the second highest mean ability level for all response categories and with a point-biserial correlation of 0.07. Some of the lowest point-biserial scores for categories 0, 7, 8, and 9 with negative point-biserial correlations of -0.02, -0.21, -0.23, and -0.15 respectively also had the low mean respondent ability levels of 0.02, -0.84, -0.61, and -0.30.

The p-values merely indicate the probability that the point biserial correlations are significantly different from zero. The mean ability values in the item analysis thus provide important information since the less favourable the response category towards the 'ideal' STS position, the lower the mean ability value. The mean ability values indicate the relative degree of strength and coherence of a response category, with the stronger and most coherent response categories having the highest mean ability values. Hence, the mean ability levels for Category 4 (0.53) and Category 3 (0.35) indicate response categories closest to the 'ideal' STS position.

In those few cases where discrepancies were observed, it was considered important to re-consider the scaling, since the students were found, overall, to have quite strong, coherent and well-directed views towards STS. The review of the literature was taken into account during this process of further reflection upon the scores allocated to each of the responses.

The overall consistency between the scaled response categories and the total scores of the students on the scale is given by the item discrimination index. In general, these indices are moderate or strong and the value of 0.47 is recorded for Item 3. The fit of the item to the unidimensional scale is given by the infit mean square, with an expected value of 1.00 for an item that discriminated well. In the analysis of the trial data, one item with infit mean square 0.80 was found to discriminate too well, and another item with an infit mean square value of 1.22 did not discriminate well enough. Table 7.3 shows that for Item 3, the calculated value of the infit mean square deviated only slightly (1.06) from the expected value of 1.00.

Item Threshold Estimates

The item estimate or threshold table for students for the society scale (see Table 7.4) shows the thresholds (between 1-4), and the infit and outfit mean square and t values for each item. It also shows the score for the item using score values (0 to 4) and the maximum overall score. The infit mean square values show the overall fit of the item to the scale across all positions on the scale, and all persons in the sample. The infit mean square values should be within the range of 0.83 to 1.20 for the item to be considered to fit the model well.

The item threshold statistic shows the difficulty level for a response category of an item (Masters, 1993). Table 7.4 shows that for Item 3, the transition levels at the 0.5 probability level of response from the score of 0 to 1, from 1 to 2, from 2 to 3, and from 3 to 4 are given by the threshold levels of -1.75, -0.13, 0.41, and 0.73 respectively.

These threshold values form a clear monotonic sequence with relatively small errors (approximately 0.10) involved in estimation. The threshold for a score of four is 0.73, which is higher than the threshold of 0.41 for a score of three (see Table 7.4). As expected, the threshold for a score of one is -1.75, which is substantially lower than the threshold for the higher scores. Consequently, the item estimates for this item conform well with the requirements of the model. The infit and outfit mean square values and t-values for this item are also within the range (approximately one), which indicates that the item discriminates consistently with the other items.

Table 7.4 Item estimates (thresholds) in input order: students on Society Scale (N = 1278; L = 9)

Item Name	Score	Max[a]	Thurstone Thresholds 1	2	3	4	Infft[b] Mnsq	Outfft[c] Mnsq	Infft[d] t	Outfft[e] t
Item 3	2949	5112	-1.75	-0.13	0.41	0.73	1.06	1.08	1.8	1.8
			0.16	0.09	0.09	0.10				
Item 5	2613	5112	-2.03	-0.33	0.80	1.33	1.05	1.07	1.3	1.5
			0.16	0.11	0.11	0.10				
Item 9	3125	5112	-1.09	-0.45	0.37	0.67	1.02	1.02	0.6	0.4
			0.11	0.12	0.09	0.10				
Item 12	2819	5112	-1.08	-0.37	0.43	1.35	1.05	1.05	1.4	1.0
			0.11	0.10	0.09	0.11				
Item 15	2829	5112	-0.47	-0.17	0.34	0.73	1.00	0.97	-0.1	-0.5
			0.09	0.09	0.10	0.10				
Item 19	3213	5112	-0.56	-0.24	-0.07	0.85	0.94	0.90	-1.7	-1.8
			0.11	0.11	0.10	0.09				
Item 21	2943	5112	-0.97	-0.20	0.38	0.74	0.96	0.95	-1.3	-1.0
			0.09	0.10	0.08	0.09				
Item 23	3115	5112	-0.48	-0.25	0.22	0.49	0.98	1.01	-0.7	0.2
			0.09	0.09	0.09	0.08				
Item 25	2543	5112	-0.38	-0.10	0.57	0.83	1.03	1.03	0.8	0.6
			0.09	0.09	0.08	0.11				
Mean				0.00			1.01	1.03	0.2	0.2
SD				0.13			0.04	0.06	1.2	1.2

a: maximum score b: infit mean square values c: outfit mean square values d: infit t values
e: outfit t values

However the outfit mean square value is primarily used to assess the fit of persons to the model, and the t-statistics are heavily influenced by sample size and in this study with 1278 students, are not taken into consideration. Nevertheless, it should be noted that for this scale both the infit and outfit t-values are less than the critical level of 2.0 for non-fit of an item to the scale.

Calculating Perfect Scale Scores

Table 7.5 shows the score equivalence for all score values on *Society*. Since the computer program did not calculate perfect scale scores, it was important to estimate the score for students on the three scales who gained a maximum score. This was accomplished by consulting the score equivalence tables for the three scales and using the top three logits for calculations.

Table 7.5 shows that the maximum score is 36. The logits for scores of 33, 34, and 35 are 1.60, 1.93 and 2.51 respectively. The maximum logit is calculated by adding: the logit for maximum score (35) shown on the score equivalence table (2.51); the difference between 2.51 and 1.93 (0.58) and the difference between 0.58 and 0.33 (1.93 minus 1.60). The figure obtained from subtracting 0.33 from 0.58 is 0.25. Thus, the maximum logit = 2.51+ 0.58+ 0.25= 3.34.

Maps of Respondents and Item Thresholds

The maps of respondents and item thresholds for the *Society*, *Science* and *Scientists* scales are shown in Figure 7.1 and in Appendices 7.1 and 7.2 respectively. These maps show the location of the item thresholds and the respondents on the scales. The clustering of the item levels provides solid evidence for the internal consistency and validity of both the model and the scores obtained as a result of the study. Both person and item responses are shown in the maps for the three scales so they are extremely useful for the subsequent analysis of observed responses. There is more than one threshold per item on these maps because it has employed the partial credit model.

Table 7.5 Score equivalence table: all scores on Society Scale (N = 1426; L = 9)

Score max = 36	**Estimate (logits)**	**Error**	**Transformed Estimate** Unit = 1.00, Origin = 0.00	**Transformed Error**
35	2.51	0.91	2.51	0.91
34	1.93	0.64	1.93	0.64
33	1.60	0.51	1.60	0.51
32	1.37	0.45	1.37	0.45
31	1.19	0.39	1.19	0.39
30	1.04	0.36	1.04	0.36
29	0.92	0.34	0.92	0.34
28	0.81	0.32	0.81	0.32
27	0.71	0.31	0.71	0.31
26	0.62	0.29	0.62	0.29
25	0.53	0.28	0.53	0.28
24	0.46	0.28	0.46	0.28
23	0.38	0.27	0.38	0.27
22	0.31	0.27	0.31	0.27
21	0.24	0.26	0.24	0.26
20	0.17	0.26	0.17	0.26
19	0.10	0.26	0.10	0.26
18	0.04	0.26	0.04	0.26
17	-0.03	0.26	-0.03	0.26
16	-0.10	0.26	-0.10	0.26
15	-0.17	0.26	-0.17	0.26
14	-0.24	0.27	-0.24	0.27
13	-0.31	0.27	-0.31	0.27
12	-0.39	0.28	-0.39	0.28
11	-0.47	0.29	-0.47	0.29
10	-0.56	0.30	-0.56	0.30
9	-0.65	0.32	-0.65	0.32
8	-0.76	0.33	-0.76	0.33
7	-0.88	0.36	-0.88	0.36
6	-1.02	0.38	-1.02	0.38
5	-1.19	0.43	-1.19	0.43
4	-1.40	0.48	-1.40	0.48
3	-1.67	0.56	-1.67	0.56
2	-2.08	0.71	-2.08	0.71
1	-2.78	0.99	-2.78	0.99
36 (estimate)	3.34			

On these maps, the location of the item thresholds show that the levels associated with threshold Level 4 in the main are above levels for threshold Level 3, which are higher on the scale than thresholds for Level 2. This further confirms the consistency of the scores assigned to the responses for the items in the instrument used in this study. Furthermore, the map also shows that the item thresholds are not equally spaced, but are located at particular levels on the latent trait scale. Likewise the persons are located at particular levels on the latent trait scale. The higher the level of the person on the y-axis, the greater the probability that he or she will give a strong and coherent response to an item. Likewise, the higher the level of a response threshold on the y-axis, the greater the strength and coherence of this response towards STS.

2.0					
	x				
	x	5.4	12.4		
	x				
	xxx				
1.0	xxxx				
	xxxxxx	5.3	19.4	25.4	
	xxxxxx	3.4	15.4	21.4	
	xxxxxx	9.4			
	xxxxxxxx	25.3			
	xxxxxxx	12.3	23.4		
	xxxxxxxxxxxxxxxxxxxx	3.3	9.3	15.3	21.3
	xxxxxxxx				
	xxxxxxxx	23.3			
	xxxxxxxx				
0.0	xxxxxxxxxxx				
	xxxxx	3.2	19.3	25.2	
	xxxx	15.2	21.2		
	xxxxxxxx	19.2	23.2		
	xxx	5.2	12.2	25.1	
	xx	9.2	15.1	23.1	
	xx	19.1			
	xx				
	x				
	x				
-1.0	x	21.1			
		9.1	12.1		
	x				
		3.1			
-2.0		5.1			
	x				

Each X represents 10 students   Scale zero set at mean of item thresholds

Figure 7.1 Map of respondents and item estimates (thresholds): all students on Society Scale (N = 1278; L = 9)

Comparison with Other Methods Used to Validate Attitude Scales

There are many similarities between the method of validation used for the attitude scales developed previously by other researchers (Thurstone and Chave, 1929; Rubba, Bradford and Harkness, 1996) and the validation of the scales developed in this present Australian study. Whereas in the present study, the experts' scaling followed the authors' scaling of the items based on a review of the literature and the authors' judgment, in both Thurstone and Chave's study and the study by Rubba, Bradford and Harkness, the scaling was performed exclusively by the panelists. In this present study, mathematical techniques discussed in this chapter were used to establish the agreement between the experts' scores and the scale scores allocated by the researcher on the basis of the review of the literature.

Although Rubba and his colleagues scaled the VOSTS instrument in their study, and used the views of the experts to validate the scales, as has been accomplished in this present study, they did not examine the items and the response categories in a way that has been done in this study. These American researchers just assumed that the experts had given the correct responses. In this present study it was considered important to calibrate the scaled information. As discussed in this chapter, procedures to establish the validity and consistency of the scales were an important part of this present study.

Consideration of the validity of scientific attitude scales used in previous studies further highlights the appropriateness of the methods that were used in this present study to establish the validity of the items in the scales. The Scientific Attitude Inventory (SAI) (Moore and Sutman, 1970) was revised by Moore and Foy (1997) in order to improve readability and remove gender-biased language. There had been criticism of the validity of the original instrument (Munby, 1983). This criticism was even more pronounced in regard to the revised instrument (Munby, 1997). These criticisms were quite important and worthy of consideration. During the process of the revision of the SAI, the researchers argued that the validity for the original instrument, which was established using the judgments of a panel of judges, was maintained in the final SAII instrument, since the position statements in the instrument had not been changed. The authors wrote that:

> ..since there is evidence for the content validity of the items in the original instrument with respect to the 12 position statements, we decided to make as few changes as possible while responding to criticisms and suggestions. This evidence was presented in item selection and the field test of the original SAI. (Moore and Foy, 1997, p. 329)

In the original instrument, attitude statements were selected for use from a pool after the judges judged each attitude statement in terms of whether it represented a particular position statement (Moore and Sutman, 1970). This method of validation differs substantially from the method employed to validate the scales used in this study. In this present study, a panel of seven experts from the Australasian Association for the History, Philosophy and Social Studies of Science provided independent scoring of the items in the scales. As has been discussed in this chapter, in this present study, the agreement between the experts' scale scores and those of the researcher was established using well-recognised statistical techniques.

The construct validity of the original SAI was demonstrated in a field test (Moore and Sutman, 1970). During this test, the SAI was administered to three groups of low-ability tenth-grade biology students. The investigator presented lessons to each of these groups. The series of lessons for the first group, the control group, was the regular sequence prepared by the teacher of this group. The other two groups received lessons that were specially designed to develop the attitudes assessed by the SAI. The authors believed that since both of the second two groups who received instruction relevant to the development of the scientific attitudes in the SAI had significantly higher post-test means than the post-test means of the control group, this field test showed that the SAI had construct validity. Munby (1983) questioned this method by which Moore and Sutman (1970) believed they had validated the SAI instrument. He argued that it was not certain what was measured by the SAI, and many of the items in the SAI, which were believed to gauge attitudes, could be interpreted quite differently. After his study of the SAI Munby contended that "there are sufficient grounds for judging the SAI to be conceptually doubtful if not weak" (Munby, 1983, p. 157).

After their redevelopment of the SAI, Moore and Foy (1997) claimed that they attempted to show the validity of SAI II with confirmatory factor analysis of the data from 557 respondents. However, this produced a reduced number of items in five scales, and the grouping of these items was not very satisfactory in attempts to give meanings to these groups. The authors concluded that:

> ..regrouping the items would virtually eliminate the support gained by judges for the validity of the instrument. Therefore, the 40-item SAI II is being advanced as presented here without the support of factor analysis. (Moore & Foy 1997, p.332)

In the present study the internal consistency of the scales was established using Rasch scaling, as discussed in this chapter. This method also demonstrated the consistency of students' views on STS. Later in the study the mean scores for students on the scales were used to show that students had strong and coherent views on STS. These findings cast doubt upon Moore and Foy's assertion in regard to their redeveloped SAI II scale that:

> ..it is possible that the objects of the scales are so ill-formed in the subjects, students in this case, that we are not able to use their responses to confirm the scales as factors. (Moore and Foy, 1987, p. 333)

Munby (1997) was rightfully very critical of Moore and Foy's claims in regard to the validity of the SAI II instrument. He showed that empirical work with the SAI II raised doubt about its validity. Munby decried the statement by Moore and Foy about the objects of the scales being so ill formed that it was not possible to use student responses to confirm the scales as factors.

Munby argued that:

> This statement suggests that the authors put more credence in the evidence of validity obtained from the panel of judges using the older version of the SAI than they do in the empirical determination using the present version. (Munby, 1996, p. 338)

In this chapter, both the empirical methods and the validation by a panel of experts, which were used in the development of the scales employed in the present study, have been discussed in detail. Moreover, the validation by a panel of experts differed substantially from that used by Moore and Foy. In this present study, examination of the scores of the researcher and the experts employed statistical techniques to show the validity of the scoring of the scales. Rasch scaling was also used to examine the fit of the empirically derived responses to the scales. The need to establish the way in which the empirically derived responses corresponded with the scales was supported by Munby (1996).

Once the fit of the student information to the scale to establish the consistency of the scoring of the scales, and the validity of the scales had been ensured, the investigator could proceed with confidence.

Summary

The scales used in this present study were developed from items in the VOSTS inventory, with careful consideration of the nature of the items to use in the final instrument, as well as the consistency and the validity of the scales. As a first step in the development of the scales, each of the response categories was assigned a numerical score based on a judgment of its degree of consistency with the "ideal" STS view. The final instrument was prepared after the examination of the data collected during the trial study. During the trial study, there was a need to reduce the number of items in the scales so that students were able to respond to the scales in one class period. Moreover, items from the trial study instrument were eliminated due to: (a) insufficient clarity of the item; (b) duplication of issues in the instrument; or (c) inconsistency established by analysis of the items using Rasch scaling.

The trial data were used to examine whether the items discriminated sufficiently between respondents who were high on the scale and those who were low. The numbers of students who selected particular scaled responses were shown on maps for each scale, where the vertical axis represented the overall levels of strength and coherence towards STS of respondents' views. The QUEST program worked out the thresholds where one scaled response changed to another and these Thurstone thresholds have been presented in this chapter. It was expected that most of the very strong and coherent scores (fours), would be at the top of the graph. This was found to occur.

Consequently, after the data for the pilot study were entered and processed, the consistency of each item to its scales was analysed, since the values provided for a test of goodness of fit for individual items to the particular scales. It was possible to use the Rasch scaling to investigate the fit of the model to the data, because this Rasch scaling model places people and items on the same interval scale. Infit mean squares were used to establish the fit between the model and the data. Items that did not conform to the model were eliminated, due to their inability to differentiate the strength and coherence of respondents' views towards STS in a manner that was consistent with the other items. This analysis of the data also examined the item analysis results for observed responses, item difficulty level estimates or threshold values and maps of respondents and items for each scale.

In this chapter the development of the scales used in the instrument has been described. The construction of the *Society* scale has been considered in some detail. The construction of the *Science* and *Scientists* scales was undertaken in the same way and information to support the use of these scales is given in the Appendices. The issues of validity and internal consistency have also been considered.

A detailed literature review was an additional form of validation of the scale values assigned to the responses for the items in the instrument. This literature review forms the basis of Chapter 6. The establishment of the validity of the scales by comparison with the views of the experts is discussed in this chapter. The first investigation, which was enabled by the scales developed during this Australian study, was an analysis of factors affecting the strength and coherence of students' views on STS. The findings of this analysis are the subject of the next chapter.

8

Students' Views on STS

At the present time, in South Australia, the examination of students' views towards STS is opportune, since the inclusion of STS objectives in senior secondary science curricula in South Australia is a fairly recent event. Factors that influence the success of curriculum innovations such as this include, among others, the reactions of the students and the views and attitudes of the students to the curriculum, as well as the views and attitudes of the teachers (Fullan, 1982). Consequently, those responsible for a curriculum change should consider how student reactions might be obtained at the time of the introduction of the innovation and successively throughout the period of implementation. This knowledge could improve the success rate of this educational change (Fullan, 1982). It is, therefore, important to consider the factors that influence the strength and coherence of students' views towards STS.

The Need to Consider Students' Views on STS

The views of students on STS-oriented issues are an important subject for research, since STS courses are expected to influence students' beliefs, attitudes and career choices (Aikenhead, Fleming and Ryan, 1987; Fleming, 1987; Zoller et al., 1991). Fleming (1986) suggested that students used their pre-existing views, understandings and intuitions about the social domain to analyse and deal with STS issues. This implies that a consideration of students' views and understandings might enable teaching materials to be structured in a way that builds upon the views and understandings brought to the classroom by the students. Thus, studies of students' views on STS are needed to guide the design of teaching materials as well as course evaluation and further development (Zoller et al., 1991).

Apart from assisting the development of teaching materials and curricula, it is necessary to know the views and understandings of students at the beginning of curriculum changes so that the evaluation of the effectiveness of the introduction of the new curriculum can include changes in students' views and understandings. From an evaluative study, Ebenezer and Zoller (1993) concluded that although the major findings of their work were that students in secondary schools in British Columbia preferred science courses which included discussion of STS issues, no changes in students' views or attitudes towards school science could be detected in spite of the impact of the STS approach on the content and processes of the science curriculum. The Australian secondary school system might be very different from the system in British Columbia, and similar studies to that of Ebenezer and Zoller have not been conducted. As a consequence, further study on the impact of the inclusion of STS objectives into secondary science curricula on Australian students' views of the interrelationships between science, technology and society is required.

The Relationship Between Views on STS and Effective Student Learning

Songer and Linn (1991) found that it was important to characterise the beliefs that students held about science, since there was a relationship between these beliefs and the students' integration of scientific knowledge. The authors believed that students with a dynamic view of science had a more accurate understanding of the work of scientists within modern societies. Songer and Linn (1991) suggested that since a dynamic view of science accompanied greater understanding of scientific principles, science courses should address students' views and attitudes towards science. Furthermore, these authors asserted that effective instruction enabled students to sift through their intuitive conceptions of science and combine predictive intuitions into scientific principles.

A dynamic view of the nature of science requires an understanding of both the social construction of science and the discontinuities in the progression of scientific knowledge (Songer and Linn, 1991). Since these views and attitudes towards STS might accompany greater understanding of scientific principles, this suggestion provides further support for the need for an improved awareness of students' views.

In a study of science education in ten countries in 1984, consistently positive relationships between science achievement and attitudes towards science including: interest in science, ease of learning science and career interest in science were found by Keeves and Morgenstern (1992). These authors concluded that a higher level of achievement in science was, in general, associated with greater support for and more favourable attitudes towards science. However, it is significant that in this Second IEA Study of Science, a greater awareness of the possible harmful consequences of science and technology was not found to be associated with stronger performance in science (Keeves and Morgenstern, 1992). Strong and coherent views towards STS entail an appreciation of the limitations of science and technology to solve social problems as well as favourable attitudes towards science and technology. It should be expected that students with strong performance in science would continue with their education and gain professional qualifications. After completing their tertiary education in science courses many of these science graduates would be working in prominent positions involving decision-making in relation to science and technology. This necessitates a valid understanding of STS issues. Consequently, it is important to examine whether science in secondary schools is being taught in a manner that enables students to develop strong and coherent views towards STS. This is one of the important aims of this present study.

An understanding of the nature and epistemology of science is necessary before an effective understanding of STS issues can be developed (Ziman, 1980). The study by Songer and Linn (1991), which concluded that students' views about science complemented their development of scientific knowledge, also reported results which strongly supported the suggestion that students were likely to gain a more integrated understanding of science if their courses emphasised knowledge about the nature of science.

An adequate understanding of the nature of science is built upon answers to questions regarding the values and assumptions inherent in scientific knowledge. Lederman (1986) suggested that these questions related to whether scientific knowledge was: absolute or tentative, moral or amoral, a direct account of observation and objective explanation or a product of human imagination. An investigation (Linn, et al., 1991) of students' perceptions of the nature of scientific models has shown that many students see scientific models as copies of observations rather than as explanations or conjectures about relationships. These authors found that this understanding held by students of scientific models was inadequate. Linn et al. (1991) believed that students were empowered to achieve greater understanding of scientific concepts when they developed a more realistic understanding of scientific epistemology, especially in relation to the ideas of uncertainty and qualitative reasoning.

The Adequacy of Australian Students' Views on the Nature of Science

There is some evidence that Australian secondary science students might not have an adequate understanding of the nature of science. Griffiths and Barman (1993) reported that the views of Western Australian secondary students demonstrated an inadequate understanding of the nature of science and the nature of scientific knowledge. The authors found that these students: (a) did not understand the meaning of terms such as fact, law and theory; (b) did not possess a realistic understanding of the scientific method; (c) did not view change in science as a revolutionary and evolutionary process; and (d) held an inductive view of science.

For this present investigation it is necessary to consider the findings of Griffiths and Barman's study, since they claimed to draw attention to a serious shortcoming of Australian science education. It is important to ask if senior secondary science education in Australia, and more specifically South Australia, is increasing students' understanding of these important issues. The three scales used in this study sought to assess the students' views of the nature of science and the nature of scientific knowledge in terms of: (a) the effects of society on science and technology, (*Society*); (b) the effects of science and technology on society (*Science*); and (c) the characteristics of scientists (*Scientists*).

This chapter examines South Australian senior secondary students' views in relation to STS on the three scales of the questionnaire. Consideration of both the research questions of this study, and the models of performance in science advanced by Keeves (1990), led to the choice of the variables to be included in the statistical analysis of students' views on STS.

The discussion in this chapter considers the influence of these variables on the strength and coherence of students' views on STS issues. First, there are variables that relate to students' participation in science at the secondary school level:

(a) marks in science,
(b) liking of science, and
(c) science subjects studied in 1995.

Secondly, there are variables that relate to students' expectations of their future participation in science:

(a) years of further education,
(b) science subjects in further education,
(c) course chosen for further education, and
(d) occupation after school.

Thirdly, there are the variables that relate to students' home backgrounds:

(a) father's occupation, and
(b) mother's occupation.

Finally, there are the variables that relate to social and economic context and location of the schools:

(a) type of school;
(b) location of school; and
(c) socioeconomic status of school.

Participation in Science at the Secondary School Level

The curriculum shift towards the inclusion of STS objectives in secondary school science curricula might be expected to have increased students' understanding of the nature of science. While an Australian study found that some students had an inadequate understanding of the nature of science (Griffiths and Barman, 1993), Solomon et al. (1994) found that British students' views of the nature of science changed when students considered STS issues in their classes. In Solomon et al.'s study, stories about the activities of scientists provided evidence for the methods of science from the world of practising scientists. This approach made the study of scientific content more accessible by providing students with practical examples of the scientific method. A relationship that was investigated in this section is concerned with whether high marks in science are related to strong and coherent views towards STS. The relationship between students' liking of science and the strength and coherence of the students' views towards STS was also of interest. It has been suggested that the inclusion of STS in science classes motivates students and provides a context for the concepts discussed, thereby increasing students' liking of science (Waks and Prakash, 1985; Holman, 1986).

One of the STS objectives, which has featured in secondary science courses in Australia and overseas, is related to the social relevance of the scientific concepts, that arises from the complex socially-embedded nature of science and technology (Cutcliffe, 1990). Cutcliffe provided further detail of this view of STS when he suggested that an objective of STS education was to present the interdependence of science and technology with human values as well as cultural, political and economic institutions.

Marks in Science

The effect of students' achievement, in terms of marks gained in science subjects, on the strength and coherence of their STS views, is of interest in this study. The results of this analysis for the three scales are shown in Table 8.1. A positive effect size shows that students with higher marks in science than in most other subjects held stronger and more coherent views on STS than those students whose marks in science were usually lower than in most other subjects.

The responses to this question on the effect of students' marks in science on the students' STS views are organised into three groups which classified the students' marks for science as usually being: (A) better than in most other subjects, (B) about average compared with other subjects, or (C) worse than in most other subjects. The evidence suggests that there are statistically significant differences for all three scales.

Table 8.1 shows that an interesting difference occurs for the *Science* scale, where medium effect sizes are apparent for the following comparisons: (a) students who gained higher marks in science than in most other subjects and those students who gained lower marks for science than for most other subjects; and (b) students who gained about average marks in science compared with most other subjects and those students who gained lower marks for science than for most other subjects.

Table 8.1 Marks in science - views on Society, Science and Scientists Scales

Group	N[a]	F[b] ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size [f]	Effect Size Category [k]
Society	1190	12.93	S	0.224	0.575			
A-better[g]	225			0.316	0.510	A-C	0.52	Medium
B-average[h]	744			0.268	0.543	B-C	0.43	Small
C-worse[i]	221			-0.019	0.672	A-B	0.08	Trivial
Science	1190	10.28	S	0.331	0.533			
A-better[g]	225			0.412	0.510	A-C	0.53	Medium
B-average[h]	744			0.366	0.510	B-C	0.44	Medium
C-worse[i]	221			0.131	0.581	A-B	0.09	Trivial
Scientists	1190	15.77	S	0.416	0.580			
A-better[g]	225			0.487	0.557	A-C	0.59	Medium
B-average[h]	744			0.476	0.576	B-C	0.57	Small
C-worse[i]	221			0.144	0.537	A-B	0.02	Trivial

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Non significant (NS); d: Standard deviation; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the combined group standard deviation; g: Students' marks for science described as usually being better than in most other subjects; h: Students' marks for science described as usually being about average compared with other subjects; i: Students' marks for science described as usually being worse than in most other subjects; k: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

For the *Society* and *Scientists* scales, the differences appear to have come mainly from between those students who gained higher marks in science than in most other subjects and those students who gained lower marks for science than for most other subjects. The finding in secondary students of a relationship between high levels of academic achievement and strong and coherent views on STS extends the findings by Keeves and Morgenstern (1992) that a higher level of achievement in science was, in general, associated with greater support for and more favourable attitudes towards science.

On all three scales, there is only a trivial difference between the mean scores for the strength and coherence of views towards STS of those students who gained average marks for science and those students who gained higher marks for science than for most other subjects. The mean scores for those students who believed that their performance in science was worse than that in most other subjects shows that these students were not able to respond strongly and coherently to the STS issues raised. This finding might be related to: (a) insufficient scientific knowledge and understanding; (b) lower reading and thinking skills; or (c) a lower level of teaching of STS issues to these students in a crowded curriculum.

Liking of Science

A further comparison, which is of interest to consider, is the effect of students' liking of science on the strength and coherence of their views towards STS. Table 8.2 shows the results for students on the three scales and the effect sizes of the differences between students in relation to their liking of science. A positive effect size shows that students who liked science more held stronger and more coherent STS views than students who liked science less than most other subjects.

Table 8.2 Like science - views on Society, Science and Scientists Scales

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[k]
Society	1212	18.14	S	0.219	0.589			
A-more[g]	222			0.364	0.495	A-C	0.53	Medium
B-same [h]	501			0.320	0.523	B-C	0.46	Small
C-less[i]	489			0.050	0.649	A-B	0.07	Trivial
Science	1212	15.34	S	0.325	0.546			
A-more[g]	222			0.452	0.508	A-C	0.50	Medium
B-same[h]	501			0.410	0.508	B-C	0.42	Small
C-less[i]	489			0.181	0.546	A-B	0.08	Trivial
Scientists	1212	15.37	S	0.413	0.585			
A-more[g]	222			0.524	0.537	A-C	0.46	Small
B-same[h]	501			0.517	0.558	B-C	0.44	Small
C-less[i]	489			0.257	0.598	A-B	0.01	Trivial

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Non significant (NS); d: Standard deviation; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the total standard deviation; g: Student response - I like science more than most other subjects; h: Student response - I like science about the same as other subjects; i: Student response - I like science less than other subjects; k: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

The responses to this question on students' liking of science are classified into three groups: (A) I like science more than most other subjects; (B) I like science about the same as other subjects; and (C) I like science less than other subjects. Analysis of the data provides evidence that there are statistically significant differences on all three scales.

On all three scales, those students who liked science less than other subjects had much less coherent and weaker views on STS than students who liked science either more than other subjects or about the same as other subjects. For both the *Society* scale and the *Science* scale, there is similar pattern of responses for the three groups, and the differences have arisen mainly from between those students who liked science the most of all of their subjects and those students who liked science the least of all of their subjects. However, it is of interest to note that for the *Scientists* scale, there is only a small effect size associated with the comparison of the mean scores for those students with a great liking of science and those students who liked science the least of all their subjects. The highest mean scores for the strength and coherence of all students' views on STS are also seen for this scale, which included questions on the characteristics of scientists.

The review of previous research indicates that the inclusion of STS in science classes provides students with both the opportunity to see the relevance of the science concepts discussed (Fensham, 1988a; Rosier and Keeves, 1991), and motivation for students (Holman, 1986). As a consequence, it is expected that the inclusion of STS in science curricula would increase students' liking of science. The data collected during this present study indicate that, at this point in time, students who say that they like science score more highly on the STS scales than those who say they don't. However, no change in liking science has been measured using this research design.

Nevertheless, the relationships reported provide evidence that supports the expected effect.

Science Subjects Studied in 1995

The South Australian Certificate of Education (SACE) syllabi, which included objectives related to STS in some science subjects was introduced at the Year 11 level in 1992, and at the Year 12 level in 1993. The cohort for this present study in 1995 consisted of students from the Year 12 level, where a social relevance report was required for the satisfactory completion of Publicly Examined Subjects (PES) Biology and Chemistry. In Biology, the social relevance objective required students to display an understanding both of factors affecting the emergence of social issues of a biological nature and of the social and personal consequences of biological knowledge (Senior Secondary Assessment Board of South Australia [SSABSA], 1991a). In Chemistry, the social relevance objective was related to students' ability to understand the social importance and consequences of selected industrial chemical processes (SSABSA, 1991b). However, a social relevance report was not required from students of PES Physics, or the School Assessed Subjects (SAS) Biological Science, General Science or other science subjects. In this study in 1995, it was important, therefore, to consider the relationship between the strength and direction of students' views towards STS and the science subjects studied by students in 1995.

Physics

Table 8.3 shows the results for students on the three scales and the effect sizes of the differences between those students who studied Physics in 1995 and those students who did not study Physics in 1995. A positive effect size shows that students who studied Physics in 1995 held stronger and more coherent views towards STS than students who did not study Physics in 1995.

Table 8.3 Physics - views on Society, Science and Scientists Scales

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[k]
Society	1221	14.28	S	0.220	0.580			
A-No[g]	930			0.170	0.579			
B-Yes[h]	291			0.381	0.553	B-A	0.37	Small
Science	1221	27.96	S	0.323	0.539			
A-No[g]	930			0.266	0.530			
B-Yes[h]	291			0.507	0.527	B-A	0.45	Small
Scientists	1221	18.42	S	0.411	0.580			
A-No[g]	930			0.355	0.552			
B-Yes[h]	291			0.588	0.631	B-A	0.40	Small

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Non significant (NS); d: Standard deviation; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the total standard deviation; g: No : Groups of students who did not study physics in 1995; h: Yes : Groups of students who did study physics in 1995; k: For effect size classification see Chapter 5 and Cohen, (1969, p. 25).

The responses to this question on whether students studied Physics in 1995 are classified into two groups of students who: (A) did not study Physics in 1995; or (B) studied Physics in 1995. There are statistically significant differences associated with the study of Physics and the strength and coherence of students' views on STS. For each of the scales there is a small effect size for the comparison of the means for students who studied Physics in 1995 and students who did not study Physics in 1995.

Chemistry

It is also of interest to consider the effect of studying Chemistry on the strength and coherence of the students' views on STS. Table 8.4 shows the results for students on the three scales and the effect sizes of the differences between those students who studied Chemistry in 1995 and those students who did not study Chemistry in 1995.

The greater strength and coherence of the views on STS of students who studied Chemistry in 1995 compared with students who did not study Chemistry in 1995 is shown by the positive effect size. The responses to this question on whether students studied Chemistry in 1995 are organised into two groups of students who: (A) did not study Chemistry in 1995; or (B) studied Chemistry in 1995.

There are statistically significant differences associated with the study of Chemistry and the strength and coherence of students' views on STS. For the *Society* scale there is a small effect size for the comparison of the means for students who studied Chemistry in 1995 and students who did not study Chemistry in 1995, whereas for both the *Science* and *Scientists* scales this comparison shows medium effect sizes.

Table 8.4 Chemistry - views on Society, Science and Scientists Scales

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[k]
Society	1221	19.66	S	0.220	0.580			
A-No[g]	974			0.168	0.593			
B-Yes[h]	247			0.423	0.474	B-A	0.44	Small
Science	1221	29.59	S	0.220	0.580			
A-No[g]	974			0.265	0.544			
B-Yes[h]	247			0.551	0.453	B-A	0.53	Medium
Scientists	1221	31.20	S	0.411	0.580			
A-No[g]	974			0.346	0.558			
B-Yes[h]	247			0.665	0.594	B-A	0.55	Medium

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Non significant (NS); d: Standard deviation; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the total standard deviation; g: No : Groups of students who did not study chemistry in 1995; h: Yes : Groups of students who did study chemistry in 1995; k: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Biology

Furthermore, it is important for this study to consider the effect of studying Biology (PES) on the strength and coherence of students' views on STS. Table 8.5 shows the results for students on the three scales and the effect sizes of the differences between those students who studied Biology (PES) in 1995 and those students who did not study Biology (PES) in 1995.

There are statistically significant differences associated with the study of Biology (PES) and the strength and coherence of students' views on STS. For the *Society* and *Science* scales there are small effect sizes for the comparison of the means for students who studied Biology (PES) in 1995 and students who did not study Biology (PES) in 1995, whereas for the *Scientists* scale, this comparison shows a medium size effect.

Table 8.5 Biology - views on Society, Science and Scientists Scales

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[k]
Society	1221	5.68	S	0.220	0.580			
A-No[g]	851			0.183	0.618			
B-Yes[h]	370			0.305	0.470	B-A	0.21	Small
Science	1221	13.57	S	0.323	0.540			
A-No[g]	851			0.271	0.554			
B-Yes[h]	370			0.443	0.482	B-A	0.32	Small
Scientists	1221	7.723	S	0.411	0.580			
A-No[g]	851			0.368	0.596			
B-Yes[h]	370			0.509	0.527	B-A	0.58	Medium

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Non significant (NS); d: Standard deviation; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the total standard deviation; g: No : Groups of students who did not study biology in 1995; h: Yes : Groups of students who did study biology in 1995; k: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

In a way, which is similar to the SACE Chemistry curriculum, the SACE Biology (PES) curriculum has changed to include objectives in relation to STS. As a consequence of this curriculum change, it would appear from the data that this curriculum change might have led to stronger and more coherent student views on STS. However, it is not possible to advance this suggestion in a conclusive way, since significant differences in the strength and coherence of students' views towards STS are also shown between those students who studied physics in 1995 and those students who did not study Physics in 1995. However, it has been stated previously that the SACE syllabi for Physics in South Australia do not include STS objectives. Nevertheless, a substantial percentage of the physics students (11 per cent) in the sample in this present study were from a school in which the physics teacher required the students to write a social relevance report during their Year 11 studies, even though it was not a syllabus requirement. In addition, these effects might be due to either the nature of these science subjects, or the fact that the students who chose to study these physics courses, were in general also studying Chemistry or Biology where STS ideas were taught. Thus the results in Tables 8.3 and 8.4 are not independent. Moreover those taking Physics and Chemistry are likely to be the more able, so these latter comparisons are not likely to be independent of the earlier comparisons based on achievement. Furthermore, it is very probable that liking science correlates positively with students' perceptions of their achievement in science. Consequently the results in Tables 8.1 and 8.2 are also unlikely to be independent. Nevertheless, it is of value to examine relationships for each factor separately before considering the possibility of carrying out more complex multilevel analyses, which would allow for the lack of independence through the use of regression procedures.

SAS Biological Science

It is unfortunate that, at the time of this study, consideration of the issues of STS was not a necessary component of School Assessed Subjects (SAS), such as Biology. However, consideration of the effect of studying this course on the students' views towards STS does supply an interesting basis for discussion of the implications of the curriculum change to include STS. Appendix 8.1 shows the results for students on the three scales for the relationships between students who studied SAS Biological Science in 1995 and the strength and coherence of students' views towards STS.

There were no significant differences between the strength and coherence of views towards STS in the comparison between the students who did not study SAS Biological Science during 1995 and the students who studied SAS Biological Science during 1995. However, it is important to note that on all three scales, the views of students who studied SAS Biological Science during 1995 were of lower coherence and strength than the views of those students who did not study SAS Biological Science during 1995. A case might well be argued that such courses as SAS Biological Science and General Science lend themselves to the teaching of STS and the discussion of STS issues.

General Science

The comparison of mean scores of students who studied General Science in 1995 and students who did not study General Science enables a consideration of the effect of studying General Science on the strength and coherence of students' views towards STS. Table 8.6 shows the results for students on the three scales and the effect sizes of the differences between those students who studied General Science in 1995 and those students who did not study General Science in 1995. A positive effect size shows that students who did not study General Science in 1995 held stronger and more coherent views towards STS than students who studied General Science in 1995. For the *Scientists* scale there is a medium effect size for the comparison of the mean scores for students who studied General Science in 1995 and students who did not study General Science in 1995. This comparison on the *Science* scale shows a small effect.

Table 8.6 General Science - views on Society, Science and Scientists Scales

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[k]
Society	1221	0.92	NS	0.220	0.580			
A-No[g]	1141			0.226	0.577			
B-Yes[h]	80			0.135	0.614	A-B	0.16	Trivial
Science	1221	2.61	NS	0.323	0.539			
A-No[g]	1141			0.332	0.544			
B-Yes[h]	80			0.190	0.437	A-B	0.26	Small
Scientists	1221	4.98	S	0.411	0.580			
A-No[g]	1141			0.424	0.585			
B-Yes[h]	80			0.215	0.452	A-B	0.36	Medium

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Non significant (NS); d: Standard deviation; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the total standard deviation; g: No : Groups of students who did not study general science in 1995; h: Yes : Groups of students who did study general science in 1995; k: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

The data collected during this study of students' views on STS indicate that the group of students who participated in science subjects such as General Science and SAS Biological Science during 1995 had lower academic achievement in science, and generally did not like science more than their other subjects. Furthermore, these students had STS views of lower strength and coherence than the higher academic achievers who studied publicly examined subjects. Table 8.6 shows that on the *Society* and *Science* scales, there are no significant relationships between having studied General Science in 1995 and strong and coherent views on STS, although there is a significant relationship for the *Scientists* Scale. The finding is disturbing, since as Lowe (1993) has suggested, for many of these students, this is their only formal science education. Thus it is extremely important that these students should be provided with an opportunity to consider STS issues in General Science courses and SAS Biological Science course.

The inclusion of similar STS objectives in SAS Biology and General Science would seem to have important implications for the future Australian society. Many researchers have agreed that there is a need, which was recognised in the late 1970s, to prepare citizens to participate effectively in debate on the use of science and technology in society (Harms and Yager, 1981; McConnell, 1982).

Ormerod (1981) administered an attitude instrument to a sample of 2,200 students aged 14 years to examine the influence of the students' attitudes on subject choice. Ormerod's four scales concerned with attitudes to the social implications of science were: (a) a humanitarian scale concerned mainly with the effects of science on the human race and the environment; (b) a practical scale concerned with the practical value of science to individuals; (c) a money scale concerned with the value of science to the community; and (d) a scientist scale concerned with the characteristics and activities of scientists (Ormerod, 1981).

It is of relevance for this present study that Ormerod found relatively few significant correlations between Biology choice and strong and coherent views on the social implications of science, but significant correlations for Physics and Chemistry, which indicated that students had slightly more coherent attitudes in regard to the social implications of science if they chose to study Physics and Chemistry at the upper secondary level, but these slightly more coherent attitudes were not necessarily present in the case of Biology. There were also low but significant correlations between the outcome measures of science preference and choice on the money and scientist scales in Ormerod's study. Although in the present study, the scores of students of PES Biology were high, they were not as high as the scores of students of Chemistry or Physics. It is possible that like the British students in Ormerod's study, the South Australian students' choice to study Physics and Chemistry was related to strong and coherent attitudes towards STS.

These findings also indicate that there might be a relationship between the inclusion of STS objectives in science courses at the Year 12 level and the strength and coherence of students' views towards STS. However, a social relevance report was included in Year 12 Chemistry and Biology, but not in the Year 12 Physics curriculum. This makes it difficult to reach a firm conclusion on whether strong and coherent views on STS correlate with the inclusion of STS objectives in South Australia. Furthermore, Year 12 Chemistry and Year 12 Physics are often chosen by students who have higher academic achievement in science than those students who choose to study only Year 12 Biology as their science subject. Since it was also found that strong and coherent views on STS were related to high levels of academic achievement, this relationship exacerbates the problem of drawing firm conclusions from the examination of these data for the effect of the science subjects studied in 1995 on the strength and coherence of students' views on STS. However, Chemistry students had mean scores for views on STS that were consistently higher on all three scales than those of Physics students, so the development of strong and coherent views on STS in South Australian secondary students might be at least partially a consequence of the shift towards the inclusion of consideration of social relevance in SACE courses.

Expectations of Future Participation in Science

In Australia in recent years it has been considered important to encourage students to pursue both tertiary studies and employment in the fields of science and technology. In

1994, the National Board of Employment, Education and Training (NBEET) recommended that the Commonwealth Government should commission the Australian Science Teachers' Association to undertake a study of science graduates who had gained employment in a science and technology field, to ascertain what influenced them to pursue science at secondary, tertiary and occupational stages. It was suggested that this project could be funded as a Project of National Significance (NBEET, 1994).

Furthermore, in a recent report prepared by The Commission for the Future it was argued that students would continue to avoid further studies and careers in science and technology unless they were seen as attractive options (NBEET, 1994). Consequently, studies of changes in curricula in regard to the effect of the changes introduced on students' choices to continue with tertiary studies in science and technology are necessary. Consideration of the issues of STS provides motivation for students and allows them to see the relevance of science in their everyday lives. It would be expected, therefore, that the inclusion of STS objectives in senior secondary science curricula would have a favourable influence on students' decisions to continue with further study of science and to enter a career in a science and technology field.

Within the context of this present study it is, therefore, necessary to consider the relationship between students' STS views and future participation in science by these students. First, it is important to look at the relationship between students' expectations of future participation in science and the strength and coherence of students' views towards STS. Students' further education in science affects their future participation in scientific careers. Hence, an examination is necessary of the relationship between students' STS views and expectations of their future participation in science, including science courses and occupations.

Years of Further Education

An item in the instrument used in this study sought information on the students' expectations of continuing their education after leaving school. The responses to this item on the years of further education students expected to have after leaving secondary school are classified into three groups: (A) I expect to continue for three to four years; (B) I expect to continue for one to two years; and (C) I do not expect to continue education after leaving school. Table 8.7 shows the results for students on the three scales and the effect sizes of the differences between those students expecting to continue education after school for (A) three to four years, (B) one to two years and (C) not to continue education after leaving school. A positive effect size shows that students who expected to continue with education for three to four years, by way of example, held stronger and more coherent views towards STS than students who did not expect to continue their education after leaving school.

The evidence suggests that there are statistically significant differences between the three groups on the *Society* scale. These differences would appear to have come largely from between those students who expected three to four years of further education compared to those who did not expect to continue with further education, since the difference between these two groups has a medium effect size. Students who expected one to two years of further education show small differences compared with those who did not expect to continue their education after leaving high school. On the *Science* and *Scientists* scales there are also statistically significant differences. A comparison of the effect sizes for the three groups of responses for these two scales leads to the conclusion that the differences have arisen mainly from between those students who expected three to four years compared with those who did not expect to continue their formal education after leaving school.

Table 8.7 Views examined with respect to years of further education expected - Society, Science and Scientists Scales

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[k]
Society	1021	9.74	S	0.196	0.580			
A-3/4 y[g]	610			0.267	0.597	A-C	0.58	Medium
B-1/2 y[h]	280			0.166	0.500	B-C	0.41	Small
C- don't expect[i]	131			-0.072	0.582	A-B	0.17	Trivial
Science	1021	16.12	S	0.309	0.524			
A-3/4 y[g]	610			0.399	0.552	A-C	0.72	Medium
B-1/2 y[h]	280			0.248	0.394	B-C	0.43	Small
C-don't expect[i]	131			0.022	0.518	A-B	0.28	Small
Scientist	1021	19.39	S	0.388	0.567			
A-3/4 y[g]	610			0.500	0.594	A-C	0.75	Medium
B-1/2 y[h]	280			0.288	0.432	B-C	0.37	Small
C- don't expect[i]	131			0.077	0.541	A-B	0.38	Small

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) at 5% level or Non significant (NS); d: Standard deviation ; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the total standard deviation; g: expect to continue with further education for 3 to 4 years; h: expect to continue with further education for 1 to 2 years; i: do not expect to continue with education after leaving school; k: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Furthermore, those students who expected one to two years of further education show small differences when compared with those who did not expect to continue their studies at the tertiary level. Those students who expected one to two years of further education have small effect size differences when compared with those who expected three of four years of further education.

Science Subjects in Further Education

The next important aspect to consider involves the relationship between the students' expectation to include any science subjects as part of their further education and the strength and coherence of STS views held by these students. Table 8.8 shows the results on the three scales for students who (A) expected to include science subjects; (B) did not expect to include science subjects; or (C) did not expect to continue their education after leaving school. A positive effect size shows that those students who expected to include science subjects in their tertiary education held stronger and more coherent views on STS than students who did not expect to continue their science education.

There are statistically significant differences on all of the three scales with regard to the relationship between the students' expectation to continue their education and the strength and coherence of the students' views on STS. For each of the three scales, comparison of the effect sizes for alternative responses shows that the differences arise mainly from between those students who expected to include science subjects as part of their further education and those students who did not expect to continue their education after leaving school, since there is a large effect size for these comparisons. Furthermore, for all three scales there is a medium effect size for the comparison between those students who wished to continue their further education in areas, which did not include science subjects and those students who did not expect to continue their education after leaving school. However, those students who expected to include science subjects as part of their further education show only small differences compared with those who expected to continue with further education that did not include science subjects.

Table 8.8 Views examined with respect to science subjects in further education - Society, Science and Scientists Scales

Group	N[a]	F[b] ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[k]
Society	1204	30.55	S	0.220	0.587			
A-(ES)[g]	504			0.388	0.456	A-C	0.87	Large
B-(NS)[h]	502			0.186	0.543	B-C	0.53	Medium
C-(NE)[i]	198			-0.124	0.794	A-B	0.35	Small
Science	1204	35.89	S	0.325	0.547			
A-(ES)[g]	504			0.489	0.464	A-C	0.94	Large
B-(NS)[h]	502			0.299	0.470	B-C	0.60	Medium
C-(NE)[i]	198			-0.027	0.721	A-B	0.35	Small
Scientists	1204	35.89	S	0.412	0.586			
A-(ES)[g]	504			0.580	0.531	A-C	0.89	Large
B-(NS)[h]	502			0.384	0.538	B-C	0.56	Medium
C-(NE)[i]	198			0.057	0.666	A-B	0.33	Small

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Non significant (NS); d: Standard deviation; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the total standard deviation; g: ES : expect to include science subjects; h: NS : do not expect to include science subjects; i: NE : do not expect to continue with education after leaving school; k: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

From the consideration of these data it would appear that there is a relationship between favourable views towards STS and decisions to continue with education after school. It is thus necessary to ask: Do strong and coherent views towards STS influence students' decisions to continue with the study of science after completing secondary schooling? The analysis of variance shows only small differences on all of the scales between the group of students who expected to include science subjects in their tertiary studies and those who did not expect to include science subjects.

However, the mean scores on strength and coherence of students' views towards STS of the group who expected to include science subjects are consistently higher than those of the students who did not expect to include science. These results indicate that strong and coherent views and attitudes on STS might have some influence on students' decisions to continue with the study of science after completing secondary school. It confirms the findings of the Second IEA Science Study. In the earlier IEA study, attitudes towards science and scientific values were found to be clearly relevant in regard to participation in the post secondary study of science. Furthermore, these influences were found to be more powerful than the level of science achievement reached (Keeves and Soydhurum, 1992) after other factors had been taken into consideration.

Courses for Further Education

Finally, it is necessary to consider the relationship between the strength and coherence of the students' STS views and the students' expected courses for further study. Appendices 8.2a, b and c show the results for students on the three scales and the effect sizes of the differences between those students who expected to continue with various courses of further education after leaving school. A positive effect size shows that students who expected to continue their further education with a particular course, which is more closely related to science, held stronger and more coherent views towards STS than students who wished to pursue another course of study which was not so closely related to science.

The responses to this question on the courses for further education students expected to study after completing their secondary studies are classified into ten groups on the basis of the following groups of courses: (A) agriculture, fishing, forestry; (B) science, applied science, mathematics; (C) architecture, building, surveying; (D) art, design, music; (E) business and commercial studies; (F) education, including teacher training; (G) engineering and technology; (H) general studies and social sciences, including history, law, religious studies, psychology and sociology; (I) health sciences, including nursing and medicine; and (J) expect not to continue education after school.

The evidence presented shows statistically significant differences on all three scales. A large effect on the *Scientists* scale and medium effects on the *Science* and *Society* scales are seen in the comparison of the mean scores for students who expected to study health sciences and students who expected not to continue their education after leaving school. Similarly, students who expected to study science, applied science, mathematics or engineering and technology also have medium differences on all three scales compared to those students who expected not to continue their education after school.

Occupations After School

The final question was related to students' expectations of their future participation in science by way of choice of occupation after leaving school. The reported occupations were classified in the manner proposed by Broom, Jones and Zubrzycki (1965) based on a grouping of jobs of the same level of skill. Subsequently the occupational categories were coded on the six-point scale developed by Broom, Jones and Zubrzycki (1968) with missing data coded at scale level 6. The use of this scale in educational research was validated by Keeves (1972).

A positive effect size shows that students' choices of occupations from the upper part of the occupational classification relate to stronger and more coherent views on STS than students who chose occupations from the lower groups of the occupational classification (see Appendices 8.3a-c).

Appendices 8.3a-c show the responses to the question on the occupations students expected to enter after they had finished their schooling. These responses were classified in seven groups: (A) professional; (B) managerial; (C) clerical and related workers; (D) skilled-craftsmen and foremen; (E) semiskilled-shop assistants, operative and process workers and drivers; (F) unskilled-domestic, personal and other service workers; and (G) other. The evidence suggests that the differences between groups are statistically significant on the three scales.

The differences across the scales are of considerable interest, particularly in regard to the levels and comparisons of the mean scores on the scales for those students who expected to enter skilled and semiskilled occupations. Small differences are observed on all three scales for students who expected to enter work as a semiskilled worker compared with students who expected to work as skilled workers.

It is also interesting to note that there are small differences on the *Society* and *Scientists* scales for those students who expected to enter professional occupations compared with students who expected to be employed as semiskilled workers-shop assistants, operative and process workers or drivers.

There are medium differences on the *Science* scale between students who expected to be employed as professionals and students who expected to be employed as unskilled workers, although for this comparison on the *Society* and *Scientists* scales there are small effect sizes.

Furthermore, on the *Scientists and Science* scales, the mean scores for those students who expected to work in semiskilled occupations are higher than the mean scores of students who expected to enter all other occupations except those who expect to work in the professions.

The level of strength and coherence of views on STS for managerial occupations is in the upper section for the *Society* and *Science* scales, but not for the *Scientists* scales. It is of some concern that on the *Scientists* scale, the mean scores for the strength and coherence of the STS views of students who expect to work as managers are lower than the scores of students who expect to work as unskilled workers and clerks, since managers might have to make decisions on STS issues which have the potential to have a substantial effect on society and the environment. The understanding of this group of the nature of science and the effects of society on science and technology was of a reasonable level, but the level of their understanding of the characteristics of scientists was quite low. This group appeared to perceive economic considerations to be of greater importance than characteristics of scientists and how they work. The most serious implication of this finding is that this poor understanding of the importance of the characteristics of scientists could have quite a serious negative effect on the ability of this managerial group to make effective decisions on STS issues that involve professional scientists.

For all secondary students, classroom discussion of the issues of STS provides an important opportunity for consideration of the social relevance of advances in science and technology. All of these people require an opportunity to develop strong and coherent views on STS during their studies at secondary school so that they are able to take an active part in STS debates in the modern Australian society. However, for some students, the development of strong and coherent views on STS is even more important, because they expect to be employed in occupations where they would have a significant influence on the use of science and technology in society. These groups include students who wish to pursue further study and careers in science and technology, health sciences, business and commerce, law and politics, architecture and agriculture. People in these occupations require an understanding of STS issues since they are frequently required to be involved in making decisions relating to the use of science and technology in society. A final group, comprising the technicians, many of whom study science subjects at the senior secondary level also need an understanding of relationships between science, technology and society.

Home Background (Parental Occupation)

The data obtained during previous studies on the influence of home background on science achievement showed clear and consistent evidence of a relationship between certain home background factors and the science achievement of students. Measures of parental occupation were found to be both monotonically related to science achievement and, in general, moderately correlated with achievement (Keeves and Saha, 1991). In a Western Australian study on the determinants of career aspirations of 704 senior secondary school students aged 16 or 17 years it was found that parents and teachers were the most important influences on students' aspirations (Punch and Sheridan, 1978). Thus, it is of interest to investigate the relationship between parental occupation and the magnitude and direction of South Australian students' views towards STS. This relationship is investigated in regard to the influence of the father's occupation and then the mother's occupation

Father's Occupation

The students' responses for the question dealing with the influence of the father's occupation on the STS views of students were divided and organised into seven groups according to the ANU scale of occupations based on a grouping of jobs of the same skill type or that involved the same level of skill (Broom, Jones and Zubrzycki, 1965; 1968). For this comparison, as shown in Appendices 8.4a, 8.4b and 8.4c, there are no statistically significant relationships between father's occupation and the three scales regarding the strength and direction of students' views on STS.

Mother's Occupation

In a manner similar to the organisation of the data for the father's occupation, the students' responses to the question dealing with mother's occupation divided and organised into seven groups according to the ANU occupational scale (Broom, Jones and Zubrzycki, 1965; 1968). Appendices 8.5a, 8.5b and 8.5c show that the differences between groups are not statistically significant on any of the three scales for the effect of socioeconomic status of mother's occupation on the strength and coherence of students' views on STS. However, the scale for SES of mother's occupation was confounded by the fact that a high proportion of the students' mothers were not engaged in employment and the students would have encountered difficulties in giving their mothers' occupations.

School-level Variables

After an examination of the student-level variables that were hypothesized to influence students' views on STS, an examination of the school-level variables in relation to students' views on STS might be expected to indicate some significant effects. Keeves and Dryden (1992) have stressed the need for analyses to take into consideration important school context variables that might differ substantially between schools. Furthermore, in a evaluation of the extent of attainment of learning outcomes of an STS course in British Columbia, Zoller et al. (1991) found that students' views and positions on STS issues were contextually dependent. Thus, it is necessary to consider the effect of the type of school and location of school on the students' views on STS.

Type of School

In this examination of the effects of school and social context variables on students' views on STS it is necessary to analyse the differences in the scale scores by the governing body (of the school), or type of school. Table 8.9 shows the results for students on the three scales and the effect sizes of the differences between those students from (A) government, (B) independent and (C) Catholic schools. A positive effect size shows that students from one of the school types being considered had stronger and more coherent views on STS than students from the other school type that is being compared.

Throughout this study the belief, that science education at the secondary school level is extremely important for the future of science and technology in Australia, is maintained for two significant reasons. First, for those students who do not continue with further studies in science, this might be their only opportunity to develop an understanding of STS issues in order to be able to participate in debate and decision-making in relation to the use of science. Secondly, Table 8.9 shows only very small differences between the strength and coherence of the STS views of students in the three different types of schools. The examination, in greater detail, of these effects using HLM (Bryk and Raudenbush, 1992), would allow more rigorous testing for these effects. This HLM analysis, which is expected to give a clearer result, is discussed in Chapter 9.

Table 8.9 Analysis of scales by school type - views on Society, Science and Scientists Scales

Group	N[a]	F[b] ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[k]
Society	1278	0.95	NS	0.210	0.590			
A-Government[g]	846			0.198	0.571	A-C	0.00	Trivial
B-Independent[h]	157			0.296	0.602	B-C	0.16	Trivial
C-Catholic[i]	275			0.200	0.635	A-B	0.17	Trivial
Science	1278	2.20	NS	0.317	0.548			
A-Government[g]	846			0.298	0.530	A-C	0.02	Trivial
B-Independent[h]	157			0.438	0.561	B-C	0.24	Small
C-Catholic[i]	275			0.307	0.548	A-B	0.26	Small
Scientists	1278	3.86	S	0.408	0.582			
A-Government[g]	846			0.405	0.564	A-C	0.13	Trivial
B-Independent[h]	157			0.557	0.674	B-C	0.39	Small
C-Catholic[i]	275			0.330	0.567	A-B	0.26	Small

a : Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c : Significant (S) or Non significant (NS); d : Standard deviation; e : Comparison; f :Effect size obtained by dividing the difference between the two groups by the total standard deviation; g : Government Schools; h : Independent Schools; i : Catholic Schools; k : For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Location of School

As shown in Appendix 8.6, no significant relationship was found between the location of the school and the strength and coherence of students' views on STS in terms of differences between metropolitan and non-metropolitan schools.

Summary

In this present study, examination of the variables or factors which had a significant effect on the strength and coherence of students' views on STS showed a number of relationships for which there were statistically significant effects on all three scales (*Society*, *Science* and *Scientists*).

Significant effects were observed for the relationship between students' marks in science and the strength and coherence of students' views on STS. There was a significant difference for the comparison of the mean scores of those students who gained better marks in science than in most other subjects and those students who gained worse marks for science than for most other subjects. Those students who gained better marks in science than in most other subjects had consistently higher scores on all three scales than those students whose marks in science were not as high in science when compared with most other subjects. As well as the relationship between high academic achievement and strong and coherent views on STS, there was a relationship between liking of science and strong and coherent views on STS.

Examination of the effect of students' liking of science on the strength and coherence of students' views towards STS showed differences on the *Society* and *Science* scales which arose mainly from a comparison between those students who liked science the most of all their subjects and those students who liked science the least of all their subjects.

The comparison between the strength and coherence of the views towards STS of students who studied PES Physics, Chemistry and Biology in 1995, and students, who did not study these particular science subjects in 1995, shows significant effects for all three scales. It is of particular importance that the mean scores for students of SAS General Science and Biological Science were not high on any of the scales when compared with the scores for students in the subjects of Chemistry, Physics and Biology. Consideration of the data on the effects of having studied SAS Biological Science or General Science in 1995 highlights the need to include consideration of the issues of STS in these courses. It appears that these students were provided with little opportunity to develop strong and coherent views on STS issues. For many of these students this might have been their only opportunity to become familiar with the debate on the use of science and technology in society. It has been suggested in Chapter 1 that the ability to take part effectively in debates relating to the social use of science and technology is necessary to enable citizens to make an informed and active contribution to debates on the use of science and technology in a changing world. This situation might be rectified by the inclusion of STS objectives into the curricula of these courses.

The finding of a relationship between having studied PES Physics, Chemistry and Biology in 1995 and students' strong and coherent views towards STS is interesting. This finding indicates that there might be a relationship between the inclusion of STS objectives in science courses at the Year 12 level and the strength and coherence of students' views towards STS. However, a social relevance report was included in Year 12 Chemistry and Biology, but not in the Year 12 Physics curriculum. This makes it difficult to reach a firm conclusion, since strong and coherent views on STS were also found to be related to academic achievement.

There were also significant relationships observed between the strength and coherence of students' views towards STS and students' expectations to continue with further education after the completion of secondary school. Strong and coherent views on STS were clearly correlated with students' expectations to continue with further education after the completion of secondary school. Furthermore, students who expected three or four years of further education had higher scores on all three scales than students who either expected one or two years of further education, or who did not expect to continue with further education. This education was not, however, necessarily in areas including science subjects. This is important since, with the wide use of technology in the contemporary Australian society, those involved in the areas of law, economics and politics, are frequently involved in making significant decisions concerning STS issues.

However, there were also significant effects in regard to the hypothesized influence of expected future participation in science and students' views on STS. The mean scores for strength and coherence of views towards STS were consistently higher for students who expected to study courses involving science, such as health sciences, engineering, technology and applied science. Moreover, they were consistently higher than were the scores of students who expected to study in areas of the humanities. This finding might assist in the planning of measures to increase participation in careers in science and technology in Australia. Unfortunately, those who expected to study either agriculture or architecture, which involve consideration of environmental issues, had consistently low mean scores for the strength and coherence of views on STS. Of further concern are the low levels on the scales for the mean scores for those expecting to study towards careers in business and commerce.

Students who expected to enter careers as professionals had views on STS that were consistently strong and coherent. The strong and coherent STS views held by these students might assist them to make socially responsible decisions in relation to STS in future years. However, an area of concern resulting from the findings of this study is that students who expected to work as managers had a fairly low mean score on the *Scientists* scale. People working as managers require strong and coherent views on STS so that they are able to make effective decisions in relation to STS issues.

Using the techniques of statistical analysis discussed in this chapter, no significant relationships were found between the strength and coherence of students' views on STS and the socioeconomic status of parents' occupations. Furthermore, only small effects were found with regard to the relationship between type of school and the strength and coherence of students' views on STS. Since the students in this study were clustered into schools, it is possible that there are a number of significant relationships for variables at the school-level, and interactions between variables at the student-level and variables at the school-level, which affect students' views on STS. These relationships are discussed in the next chapter.

9

Factors Influencing Students' Views on STS

In addition to the examination of effects at the student level, it is important to consider and discuss the effects of the characteristics of the school on the strength and coherence of students' views on STS. These effects of school-level variables and student-level variables, as well as any interaction between variables from both levels on the strength and coherence of views on STS were investigated in this study by using hierarchical linear modelling (HLM). The effects of school-level variables on students' liking of science as well as students' decisions to include science subjects in their university studies were also investigated using HLM in this study. The HLM analysis and results obtained are discussed below.

HLM Analysis

In this Australian study the data structures were hierarchical, since there were variables describing individuals and these individuals were grouped into larger units, the 29 schools. There were also variables describing the higher order units, the schools. Thus, there was the possibility of relationships at more than one level. A major concern was, therefore, to relate the properties of these groups in which individuals functioned to the characteristics of individuals (Bryk and Raudenbush, 1992; Sellin and Keeves, 1994).

The general problem addressed by multi-level analysis, with data nested at different levels, is that individuals in the same group (school) are more similar to each other than to individuals from different groups (schools).

This similarity of students within schools may be due to school-specific variables, including procedures of student selection, as well to the characteristics of the teaching staff. The variables at different levels can be employed at a higher level (aggregation) or at a lower level (disaggregation). If data are aggregated to a group level strong effects can appear to be produced, and an aggregation bias results from this grouping of students (Keeves and Sellin, 1988). However, multi-level analytical models and statistical procedures designed to estimate the parameters of such models with greater accuracy than was possible with traditional single-level analysis, overcome the problem of aggregation bias (Cheung et al., 1990).

Before the availability of HLM, analysis of multi-level data was often carried out using ordinary regression analysis and the aggregation or disaggregation of data. A disadvantage of this procedure, which involves aggregation, is that information is lost (Hox, 1995). If data on the home background of students, by way of example, are aggregated to the school level, analyses of effects due to the home background of individual students are distorted.

Furthermore, ordinary regression analysis treats disaggregated data as independent information, and some of the meaning of the statistical analysis is lost. Another disadvantage of using ordinary regression analysis following disaggregation of multi-level data is that misleading levels of significance are obtained, and the standard errors are too small (Hox, 1995). Thus, misestimated precision arises when the effects of school-level variables are obtained at the student-level. For many analyses it is not possible, therefore, to use traditional statistical techniques that assume independence of observations. When using traditional statistical techniques for the analysis of multi-level data, the probability of rejecting a true null hypothesis is increased by misestimated precision on the magnitude of the estimated effect, because the assumption of single-level multivariate techniques is that one case is independent of the other cases in the analysis. As a consequence, the fundamental problem in the analysis of the data in this study was to analyse student-level variables at the student-level and simultaneously school-level variables at the level of the schools attended by these students. Thus, multi-level analysis was necessary to overcome these problems presented by traditional models and techniques of analysis. The advantages of multi-level analysis over traditional methods have been stated by Bryk and Raudenbush (1992) to include:

> (a) improved estimation of individual within-unit effects; (b) the capacity to measure cross-level effects; and (c) the ability to partition variance into between- and within-unit components. (Bryk and Raudenbush, 1992, p. 5-7)

The problems caused by aggregation and disaggregation bias may be overcome by employing analytical techniques that are able to treat the analysis of variables at two or more levels (ie the student-level and school-level) simultaneously. Multi-level analysis enables an examination of the way in which an outcome variable is influenced by a number of specified individual and group level variables. In addition to the direct effects of variables, statistical interaction between explanatory variables, where group-level variables moderate lower-level variables, may also be investigated using multi-level analysis. Hox (1995) wrote that the advantage of multi-level modelling is that:

> Multi-level models are designed to analyze models from different levels simultaneously using a statistical model that includes the various dependencies. (Hox, 1995, p. 7)

The computer program chosen for the multi-level analysis in this study, on the basis of its ability to take this hierarchical structure into account was Hierarchical Linear Modeling (HLM/2L) (Bryk and Raudenbush, 1992). With HLM/2L (Bryk, Raudenbush and Congdon, 1994), variables at the student-level and school-level were analysed simultaneously. The predictor variables, which were examined, were identified on the basis of theory and entered into the equation.

Hierarchical linear modelling works by calculating separate regression coefficients based on within-group analyses and uses these coefficients as outcome variables in a subsequent regression performed at the between-group level. The student-level variables were first entered into the Level-1 equation, with the strength and coherence of students' views on STS as an outcome, and thus multiple regression analysis was repeated for each of the 29 schools in the sample for the study. Next, the sets of regression coefficients obtained from this initial regression analysis served as outcome measures in subsequent regression analyses. In these second regression analyses, aggregated student-level and school-level variables were entered as predictor variables.

Student-level Variables

The literature review and findings of the traditional statistical analysis discussed in Chapter 10 indicate that girls are more likely to have strong and coherent views on STS than boys. However, relationships that involve the direct effects of sex of school at the group or macro level of analysis, cannot be properly detected by this traditional, single-level statistical analysis. Thus, a multi-level analysis of the relationship between the student-level variable, student sex, and the strength and coherence of students' views on STS is required. Measures of parental occupation have also been found to be related to science achievement (Keeves and Saha, 1991). Moreover, consistent positive relationships between science attitudes and science achievement have been observed (Keeves and Morgenstern, 1992). These findings indicate that an analysis of the relationships between parental occupation and students' views towards STS is also necessary. Hence, the student-level (or level-1) variables that were chosen for investigation using HLM/2L included sex of student (SSEX) and socioeconomic status level of the student's father's occupation (FATOCC).

For sex of student, the scaling employed was boys = 1 and girls = 2. The socioeconomic status of the student's father's occupation, (FATOCC), was classified using the Broom, Jones and Zubrzycki (1965) scale into seven groups: 1= professional; 2 = managerial; 3 = clerical and related workers; 4 = skilled - craftsmen and foremen; 5 = semiskilled - shop assistants, operative and process workers and drivers; 6 = unskilled - domestic, personal and other service workers; and 7 = other, including not in the workforce.

School-level Variables

A more detailed and multi-level examination of the factors that influence differences between students with regard to views on science, technology and society must include variables on the characteristics of schools. It is important for analyses to include consideration of the influence of school context variables on student learning outcomes (Keeves and Dryden, 1992).

As a consequence it is necessary to consider the effects of the type of school, as well as the school location, and other contextual factors, on the students' views in relation to STS.

The Australian Council for Educational Research (ACER) analysis of factors relevant to economic status in the Australian Science Teachers' Association study on the understanding of science and technology by Australian students, found a high correlation between socioeconomic status and students' performance in science (National Board of Employment, Education and Training, 1994). Even though the students involved in the ASTA study were at the beginning of their years of secondary schooling, rather than in the senior secondary school years like the students in this South Australian study, it was considered important, in the present study, to investigate the effects of the socioeconomic status of a school on the strength and coherence of students' views on STS.

The potential level-2 predictors for this present study include school sex (SCHSEX), school type (SCHTYPE), school location (SCHLOCAT), and average socioeconomic status of father's occupation for that school (SCHFOCC). The school average of student's father's occupation, (SCHFOCC) is a variable that is taken as an indication of the average level of socioeconomic status of student's father's occupation for the school. The occupations were classified using the Broom, Jones and Zubrzycki (1965) scale. This variable is interpreted as a measure of the socioeconomic status of the community served by the school.

The average school sex variable (SCHSEX) was created by an aggregation of the student-level measure to the group level. Thus for the school sex variable, boys' schools were coded as 1, girls' schools were coded as 2, and coeducational schools were somewhere in between, depending upon the relative numbers of boys and girls in particular schools. Since the boys and girls in the sample are correctly weighted in the analysis, this method is an appropriate way to code the school sex variable. A coeducational school with a large number of boys in it then shows up as having more boys than girls in it, thus facilitating an accurate interpretation of the results of the study.

The effects of the type of school (SCHTYPE) were examined by coding as dummy variables in order to perform two comparisons of the effects of these different types of schools on the outcomes considered in this study. Government schools were coded as 1, and non-government schools, whether Catholic or non-Catholic, were coded as 2. The final coding of a level-2 variable was for the city or country location of school (SCHLOCAT), in which metropolitan schools were coded as 1, and non-metropolitan schools were coded as 2.

The question addressed was whether characteristics of schools such as type of school (SCHTYPE), school sex (SCHSEX), average socioeconomic status of father's occupation for a school (SCHFOCC), and school location (SCHLOCAT), predicted why some schools had greater strength and coherence of students' views towards STS on the three scales, and towards liking science and future science study at university level.

In this multi-level model, both the level-1 intercept and the level-1 slopes vary randomly. This analysis permits estimation of the effects of factors that influence the variability of both intercepts and slopes across level-2 units. The dependent variables or outcome variables included a measure of the consistency of students' views towards STS on the *Society, Science* and *Scientists* scales, and the levels of students' liking of science (LIKSCI), as well as students' future science study at university (SCISUBS) after the completion of secondary school. Analysis in relation to the influence of level-2 predictors was accomplished by determining if the level-2 predictors predicted the level-1 intercepts and slopes.

Slopes and Intercepts as Indicators of Equity and Efficacy

In HLM analyses such as those discussed in this chapter, slopes and intercepts may be used as indicators of equity and efficacy respectively. Each school on a graph of the strength of student's views on STS against student's father's occupation (FATOCC) has a characteristic slope and intercept. Thus, it is possible to use these measures as an outcome of the provision of equity as well as an indication of a school's efficacy in regard to strength and coherence of STS views. The lower the magnitude of the slope coefficient for a particular school, the greater the provision of equity within that school with regard to the particular STS view being measured. The higher the magnitude of the intercept coefficient, the greater the efficacy of that school with regard to the strength and consistency of the STS view that was measured. Therefore, if a school had a fairly flat slope and a high value for the intercept when compared with another school, this first school had both greater equity and efficacy in regard to the outcome considered than did the second school.

The effect of socioeconomic status on the strength and coherence of STS views in schools of different sex was also examined. If student's father's occupation (FATOCC) was plotted against STS views for different values of school sex (SCHSEX), by way of example, it would be possible to see if father's occupation was interacting with sex of school to produce different effects. If in this analysis, boys' schools had a steep slope and girls' schools had a relatively flat slope, it would be concluded that girls schools were more equitable with regard to the effects of father's occupation on the strength and coherence of STS views than boys schools.

The Two-level Model for Analysis

Multi-level models avoid problems associated with nested data, as discussed above, by examining variability simultaneously at different organisational levels as well as variability in the cross-level interactions. Thus hierarchical linear models make it possible to incorporate variables from two or more levels (Bryk and Raudenbush, 1992). In this study, the multi-level model consists of a within-unit or student-level model and a between-unit or school-level model. Both models involve linear regression equations and the parameters in the equations are regression coefficients. When HLM is used it is also possible to specify so-called interaction or moderator effects of level-2 variables on level-1 predictors of the outcome variable.

In this Australian study, HLM employed the simplest type of multi-level model that consisted of level-1 (within unit) and level-2 (between unit) models with a student-level outcome measure. Each of the sub-models was represented by a linear regression equation and the regression coefficients (or level-1 slopes and intercepts) were the outcome measures of the level-2 equations. In order to illustrate the use of HLM in this study, an example of one of the analyses is discussed below.

At the first-level (student), the basic two-level regression model with one single dependent variable, Y (the strength and coherence of students' views on STS on the *Science* scale) is predicted by the two explanatory variables:

$$Y=B_0+B_1\ (SSEX) + B_2\ (FATOCC) + r \tag{9.1}$$

Where: B_O is the intercept 1, B_1 and B_2 are the slopes, and r is the random error.

In Equation 9.1, B_O is the intercept, or the average strength for a school of the students' STS views. Furthermore, each school has a unique value for this intercept B_O and slope coefficients, B_1 and B_2. The intercept and slope coefficients are therefore termed random coefficients. The HLM/2L program set up one of these regression equations for each school.

Furthermore, in this HLM analysis, the slopes or intercepts calculated in the analysis of the level-1 model become the outcomes in the second step. Thus, an attempt is made to explain the variation in slopes and intercepts by using characteristics of the schools.

A level-2 model associated with Equation (9.1) is:

$$B_0 = G_{00} + G_{01}\ (SCHFOCC) + u_0 \tag{9.2}$$

$$B_1 = G_{10} + u_1 \tag{9.3}$$

$$B_2 = G_{20} + u_2 \tag{9.4}$$

Where: G_{00}, G_{10}, and G_{20}, are Level-2 coefficients or fixed effects, and u_0, u_1, and u_2 are random residual error terms at the school level, which are assumed to have a mean of zero, and to be independent of the variables at the student level.

Equation (9.2) states that the general level of strength of the STS views for the students of a school (B_0) can be predicted by the school average socioeconomic status level of students' father's occupation (SCHFOCC). A negative value for G_{01} indicates that the strength and coherence of the STS views of students in high socioeconomic status schools is greater than for students in low socioeconomic status schools, because high status father's occupation is coded 1, and low status father's occupation is coded 6.

The overall multi-level regression equation obtained by substituting equations (9.2), (9.3) and (9.4) into equation (9.2) is:

$$Y = G_{00} + G_{01}\,(SCHFOCC) + G_{10}\,(SSEX) + G_{20}\,(FATOCC) + \{u_0 + u_1\,(SSEX) + u_2\,(FATOCC) + r\} \quad (9.5)$$

Cheung et al. (1990) provide a more detailed discussion of the problems encountered using these analytic procedures.

The data for the predictor variables are generally grand mean centred, as discussed in Chapter 5. Centring around the grand mean makes it explicit that the individual scores should be interpreted relative to this mean (Hox, 1995).

Analysis Using the Maximum Likelihood Estimation Procedure

The aim of the multi-level regression analysis is to estimate the regression coefficients and variance components of the multi-level regression model. This is accomplished by using maximum likelihood procedures, which estimate the regression coefficients and variance components to maximise the probability of finding the sample data that were actually recorded, and this involves maximising the likelihood function. The computation of the maximum likelihood estimate uses an iterative procedure, which begins with the computer generation of reasonable starting values for the variance components and regression coefficients. Repeated attempts are then made by the computer to generate values that are better estimates. The process continues until convergence has occurred (Hox, 1995).

The model is respecified by using different variance components or explanatory variables so that convergence commonly occurs after a reasonably small number of iterations. Selected cross-level interactions are also included. Often, the researcher starts with the intercept-only model, and then progressively tries other models, particularly those hypothesized from theory and previous research as possibly being significant. Subsequently, the result is inspected to see which explanatory variables are significant (Hox, 1995). The amount of residual variance left over at the two levels indicates how much remains to be explained as well as how much is already explained by the explanatory variables used.

Table 9.1 summarises the variables used by presenting:

- their acronyms,
- how the variables are coded, and
- the level at which they operate.

Table 9.1 Variables in two-level HLM analysis

Variable	Acronym	Code	Level at which variable operates
student sex	SSEX	0 = male; 1 = female	1
student's father's occupation	FATOCC	1= professional; 2 = managerial; 3 = clerical and related workers; 4 = skilled - craftsmen and foremen; 5 = semiskilled - shop assistants, operative and process workers and drivers; 6 = unskilled - domestic, personal and other service workers; and 7 = other, including not in the workforce.	1
school sex	SCHSEX	boys' schools = 0; girls' schools = 1	2
school type (governing body of school)	SCHTYPE	government schools = 0; non-government schools = 1	2
school average of student's father's occupation	SCHFOCC	aggregate variable with average socioeconomic status of father's occupation as coded above	
school location	SCHLOCAT	metropolitan schools = 0 non-metropolitan schools = 1	2

Multi-level Analysis of Variables Affecting Students' Views on STS

In this investigation of the effects of the within- and between-school variables, the strength and coherence of the STS views of students within a random sample of 29 schools was considered.

The intercept- and slopes-as-outcomes model was used to build an explanatory model to account for the variability of the regression equations across schools at the level-2 or macro-level and students at the level-1 or micro-level. The findings of the two-level multivariate analyses are discussed in the following section.

Society Scale

Table 9.2 shows the results on the *Society* scale for the intercept- and slopes-as-outcomes model of factors affecting the strength and coherence of students' views on the *Society* scale dimension of STS. In the first panel of Table 9.2, which shows the fixed effects, the most direct evidence of whether a predictor should be included in the analysis is provided by the size of its estimated effect and the t-ratio (Bryk and Raudenbush, 1992). T-ratios are employed to test for significance by providing a comparison of the coefficient with its standard error. Predictors with t-ratios greater than two are candidates for inclusion in the model. In this case, both the intercept B_0 and the father's occupations slope have t-ratios greater than two. The sign of the coefficient or the t-ratio provides important information to show the direction of an effect. In Table 9.2, the coefficient for the father's occupation slope at the student-level has a negative sign, which shows that the higher the socioeconomic status of father's occupation (ie the smaller the assigned SES value), the stronger and more coherent the student's views towards STS on the *Society* scale. The p-values also provide important information about the significance of predictor variables. The p-value for status of father's occupation (FATOCC) slope is 0.002, which is less than 0.05. Thus it is concluded that at the student level, the slope is significant. Each school has a unique intercept and slope.

The level-1, r value, 0.274, in the final estimation of variance components panel shows that there is a great deal of residual variance remaining in the scattering of the points about the line for the status of father's occupation (FATOCC) slope. The variance at the school-level associated with the differences in the slopes of these lines for the different schools is very small with a variance component of 0.00009. Consequently the χ^2 value for father's occupation slope (30.9) is close to the number of degrees of freedom, which shows that there is little variance left to explain. The p-value of the variance of the intercept (0.00), which is less than 0.05 shows that there is a great deal of variation remaining between the intercepts of the regression lines for each student.

Table 9.2 Results from the multi-level analysis with outcome variable Society Scale

Final estimation of fixed effects:

Fixed Effects	Coefficient	s e	t-ratio	p-value
INTRCPT 1, B_0				
INTRCPT 2, G_{00}	0.358	0.021	16.7	0.000
FATOCC slope, B_1				
INTRCPT 2, G_{10}	-0.023	0.007	-3.41	0.002

Reliability estimates Intercept 1, B_0 = O.447; FATOCC, B_1 = 0.063

Final estimation of variance components:

Random Effect	Standard Deviation	Variance Component	df	χ^2	p-value
INTRCPT 1, U_0	0.080	0.006	28	68.8	0.00
FATOCC slope, U_1	0.010	0.00009	28	30.9	0.32
level-1, r	0.524	0.274			

se = standard error; FATOCC = fathers' occupation; INTRCPT = intercept;
t-ratio = estimated coefficient/standard error.

However, in the exploratory analysis of the potential level-2 predictors to explain this variance at the school level, all of the t-values for the predictors were less than 2. For this analysis, all of the potential level-2 predictors (SCHSEX, SCHTYPE, SCHLOCAT, and SCHFOCC) had t-values which were well within the range of +2 and -2 for both the level-2 analyses of INTRCPT 1, B_0 and FATOCC slope B_1, so none of these school-level variables were of significance. The reliability estimates for these analyses, INTRCPT 1, B_0 0.447 and FATOCC, B_1 0.063 are satisfactory, although the latter coefficient is low.

Science Scale

The results for the multi-level analysis of the students' views on the *Science* scale as the outcome are shown in Table 9.3. In a similar way to the above discussion of the results for the *Society* scale, the t-ratio and p-value for the *Science* scale show that the FATOCC slope is significant.

In a way, which is also similar to the *Society* scale, for the *Science* scale, the negative sign of the coefficient for the FATOCC slope shows that students from backgrounds of high socioeconomic status have stronger and more coherent views on the *Science* scale from an STS perspective than students from backgrounds of relatively low socioeconomic status. However, unlike the results for the *Society* scale, for the *Science* scale, sex of student (SSEX) is also significant. In this case, the positive sign of the slope coefficient (boys = 0, girls = 1) shows that girls have stronger and more coherent views on STS than boys. Furthermore, the t-ratio and p-values show that there is a significant relationship between the average socioeconomic status of a school (SCHFOCC) and the strength and coherence of students' views on *Science.* The negative sign of the coefficient shows that the higher the school average status of the student's father's occupation, the greater strength and coherence of the STS views on the *Science* scale of the students attending the school. There is also a substantial amount of residual variance for the *Science* scale due to scattering. This variance at the school-level is not explained by either school status or school sex. In the exploratory analysis of the effects of the other level-2 predictors for this variance, all values were well within the range of +2 and -2, so none of the school-level variables was significant.

Table 9.3 Results from the multi-level analysis with outcome variable Science Scale

Final estimation of fixed effects:

Fixed Effects	Coefficient	se	t-ratio	p-value
INTRCPT 1, B0				
INTRCPT 2, G00	0.455	0.023	19.4	0.000
SCHFOCC, G01	-0.072	0.029	-2.4	0.022
SSEX slope, B1				
INTRCPT 2, G10	0.103	0.047	2.2	0.039
FATOCC slope				
INTRCPT 2, G20	-0.028	0.007	-4.0	0.001

Reliability estimate Intercept 1, B0 = 0.455; SSEX, B1 = 0.487; FATOCC, B2 = 0.050

Final estimation of variance components:

Random Effect	Standard Deviation	Variance Component	df	χ^2	p-value
INTRCPT 1, UO	0.088	0.008	23	58.2	0.00
SSEX slope, U1	0.179	0.032	24	42.6	0.01
FATOCC slope, U2	0.009	0.0001	24	22.1	>.50
level-1, r	0.519	0.269			

se = standard error; FATOCC = fathers' occupation; SCHFOCC = socioeconomic status of school; SSEX = sex of student; INTRCPT = intercept; t-ratio = estimated coefficient/standard error.

Scientists Scale

The multi-level analysis with the outcome variable *Scientists* produced the results given in Table 9.4. These results for the *Scientists* scale are similar to the results for the *Science* scale, since significant effects are observed for both sex of student (SSEX) and students' father's occupation (FATOCC). Students with fathers employed in careers of relatively high socioeconomic status had stronger and more coherent views on the *Scientists* scale from an STS perspective than students from backgrounds of lower socioeconomic status.

Girls also had stronger and more coherent views on the *Scientists* scale from an STS perspective than boys. Although there is also a substantial amount of residual variance for the *Scientists* scale due to scattering, this variance at the school-level is not explained by either school sex (SCHSEX) or school average of students' father's occupation (FATOCC).

No other significant relationships on the *Scientists* scale were observed from the exploratory analysis with potential level-2 predictors, since all values were well within the range of +2 and -2. Furthermore, there was little variability in the slopes of student sex (SSEX) and father's occupation (FATOCC) left to be explained since the p-values for the χ^2 test were greater than 0.10. The corresponding test for the intercepts B_0 had a p-value close to 0.10, indicating that there was little variance left to be explained.

Table 9.4 Results from the multi-level analysis with outcome variable Scientists Scale

Final estimation of fixed effects:

Fixed Effects	Coefficient	s e	t-ratio	p-value
INTRCPT 1, B0 INTRCPT 2, G00	0.372	0.018	20.6	0.000
SSEX slope, B1 INTRCPT 2, G10	0.146	0.034	4.2	0.000
FATOCC slope INTRCPT 2, G20	-0.019	0.007	-2.7	0.013

Reliability estimate Intercept 1, B0 = 0.243; SSEX, B1 = 0.199; FATOCC, B2 = 0.157

Final estimation of variance components:

Random Effect	Standard Deviation	Variance Component	df	χ^2	p-value
INTRCPT 1, UO	0.052	0.003	24	33.8	0.09
SSEX slope, U1	0.086	0.007	24	30.5	0.17
FATOCC slope, U2	0.016	0.0003	24	24.9	0.41
level-1, r	0.509	0.259			

se = standard error; SSEX = sex of student; FATOCC = father's occupation, INTRCPT = intercept; t-ratio = estimated coefficient/standard error.

Multi-level Analysis of Variables Affecting Liking of Science and Future Science Study

Further analyses that were considered useful on the basis of the review of the literature were examinations of the variables affecting students' liking of science, and students' expectations to continue with the study of science at university after the completion of their secondary school studies. In the recoding for these analyses the student-level data were not changed, but the school-level data were changed using dummy coding. One new variable was created. The variable school type (SCHTYPE), government schools were coded as 0, and both Catholic and independent schools were coded as 1. The analyses were then re-run with this school-level variable tested as an explanatory variable.

Multi-level Analysis of Variables Affecting Students' Liking of Science

The results for the multi-level analysis of the fixed effects and variance components in the hierarchical linear model with liking of science (LIKSCI) as dependent variable are shown in Table 9.5. The item, which gauged these effects, sought information on how much the students liked science. The alternative responses and scores were: (a) more than other subjects, 3; (b) about the same as other subjects, 2; and (c) less than other subjects, 1. Investigation of effects of level-1 variables on students' liking of science shows that overall, students from higher socioeconomic status backgrounds (in terms of status of father's occupation) liked science more than students from lower SES backgrounds. The student-level analysis also demonstrated that the boys in the sample liked science more than girls. The relatively simple scaling of this measure of liking science must be seen as the source of the unreliability of the coefficients recorded in Table 9.5.

The t-ratios for the fixed effects, sex of student (4.09) and father's occupation (2.04) show that these variables should be included in the model. The reliability estimates for these analyses are less than satisfactory, with FATOCC (0.028) and SSEX (0.040).

However since significant effects were recorded the results are presented as being of interest. The coefficient of the interaction between school sex and father's occupation (-0.058) shows that school sex is interacting with father's occupation to influence the dependent variable.

Table 9.5 Results from the multi-level analysis, outcome variable LIKSCI

Final estimation of fixed effects

Fixed Effects	Coefficient	se	t-ratio	p-value
INTRCPT 1, B0				
INTRCPT 2, G00	2.213	0.033	67.17	0.000
SCHTYPE, G01	0.136	0.040	3.35	0.003
SSEX slope, B1				
INTRCPT 2, G10	-0.178	0.044	-4.09	0.000
FATOCC slope, B2				
INTRCPT 2, G20	-0.018	0.010	-2.04	0.050
SCHSEX, G21	-0.058	0.034	1.71	0.099

Reliability estimate Intercept 1, B0 = 0.532; SSEX, B1 = 0.040; FATOCC, B2 = 0.028

Final estimation of variance components:

Random Effect	Standard Deviation	Variance Component	df	χ^2	p-value
INTRCPT 1, UO	0.138	0.019	23	64.8	0.000
SSEX slope, U1	0.046	0.002	24	25.9	0.359
FATOCC slope, U2	0.008	0.00007	23	22.9	>. 500
level-1, r	0.686	0.471			

se = standard error; FATOCC = father's occupation; SCHTYPE = school type; SCHSEX = school sex; SSEX = sex of student; LIKSCI = like science; INTRCPT = intercept; t-ratio = estimated coefficient/standard error.

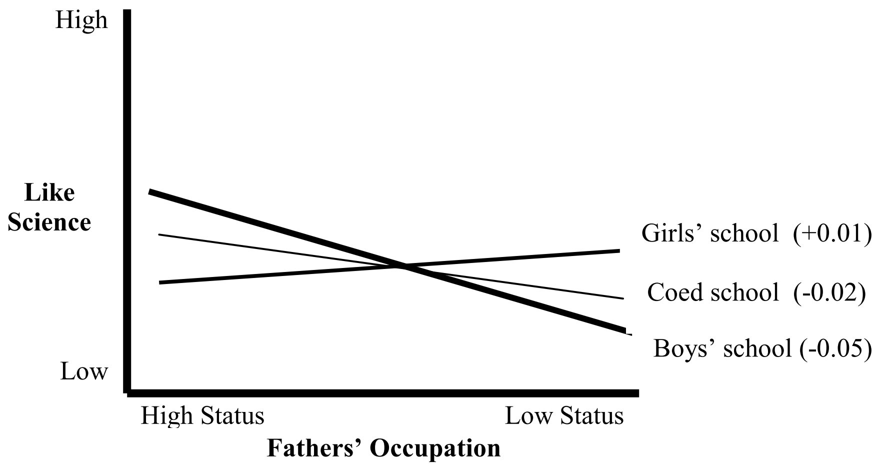
For the final estimation of variance components, the r-value (0.471) shows that a substantial amount of variance remains as unexplained. However the variance components of the SSEX slope and FATOCC slope are not large enough for further residual variance to be accounted for by macro-level variables. The exploratory analysis of all the potential level-2 predictors produced t-values, which were so small that they indicated that none of the school-level variables were significant in explaining the remaining variance in the intercepts.

Another important effect is shown in this multi-level analysis for the liking of science (LIKSCI) variable in schools from different types (SCHTYPE).

Students in government schools liked science less than students in non-government schools, since the coefficient for the school type effect (SCHTYPE) has a positive sign. For this analysis, government schools were coded as 0, and non-government schools 1. A possible explanation for this observed effect could be that there were differences in the teaching of science in these two types of schools. The laboratories might have been better equipped and better used in the non-government schools.

Another possible explanation is that STS discussions might have been included more effectively in non-government schools. As Yager (1993) has argued, the attitudes of students towards science are significantly more positive in science classes that include discussions of STS issues (Yager, 1993). It is possible that the higher scores on the *Science* scale for students in non-government schools than for students in government schools are due to the climate of these schools, as well as to the different teaching of STS issues in these schools. In these higher socioeconomic status schools there might have been factors that influenced the development, in students, of stronger and more coherent views on STS with respect to *Science* than for students in government schools. Thus, it appears that the teaching of the issues of STS in government and non-government schools might differ, and this might explain the difference in the students' liking of science in the two types of school.

There were also different effects for students' liking of science in schools of different sex (boys schools, girls schools and coeducational schools). The results of the investigation of the influence of both school sex and student father's occupation on students' liking of science are illustrated in Figure 9.1.



Y =2.21 - 0.18 SSEX + 0.14 SCHTYPE - 0.02 FATOCC + 0.06 SCHSEX.FATOCC[a] + r

a: It should be noted that in the calculations of slopes the SCHSEX variable is centred around its grand mean

Figure 9.1 The influence of the interaction between school sex and father's occupation on the student's liking of science

Analysis of the interactions between level-1 and level-2 variables shown in Figure 9.1, demonstrate relationships that differed substantially for the three school groups, since there was an interaction between school sex and father's occupation in terms of student's liking of science. In boys schools, a slope of -0.05 for the influence of father's occupation on student's liking of science shows that students from high socioeconomic status backgrounds liked science more than students from low socioeconomic status backgrounds.

In coeducational schools (slope = -0.02), students from high socioeconomic status backgrounds liked science slightly more than students from low socioeconomic status backgrounds. By way of contrast, in girls' schools, father's occupation was found to have a different effect on students' liking of science. The girls' schools slope of 0.01 indicates that there is very little difference in liking of science when students from high socioeconomic status backgrounds are compared with students from low socioeconomic status backgrounds.

Multi-level Analysis of Variables Affecting Expectations of Future Science Study

The item, which sought information on expectations of future study of science, included three alternative responses that were assigned scores between 1 and 3. The responses and scores were: (a) I expect to include science subjects, 3; (b) I do not expect to include science subjects, 2; and (c) I do not expect to continue my education after leaving school, 1. The results of the analyses for the variables affecting students' expectations to continue with further study of science are shown in Table 9.6. It should be noted however that the item also contained information on expected participation in further education as contrasted with no expectation of further education.

Table 9.6 Results from the multi-level analysis, outcome variable SCISUBS

Final estimation of fixed effects:

Fixed Effects	Coefficient	se	t-ratio	p-value
INTRCPT 1, B0				
INTRCPT 2, G00	-0.455	0.075	-5.89	0.000
SCHTYPE, G01	0.345	0.152	2.27	0.031
FATOCC slope, B1				
INTRCPT 2, G10	-0.138	0.028	-4.90	0.000
SCHSEX, G11	0.234	0.107	2.18	0.038

Reliability estimate Intercept 1, B0 = O.313; FATOCC, B1 = 0.098

Final estimation of variance components:

Random Effect	Standard Deviation	Variance Component	df	χ^2	p-value
INTRCPT 1, UO	0.236	0.056	27	42.5	0.029
FATOCC slope, U1	0.049	0.002	27	36.5	0.105

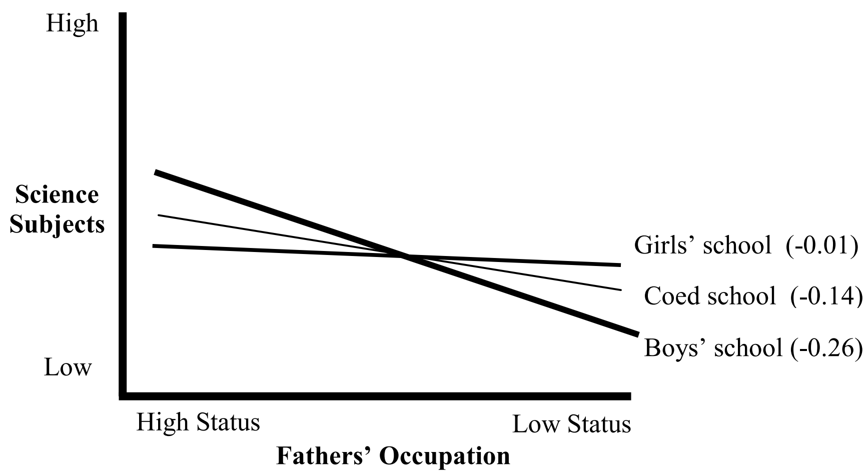
se = standard error; FATOCC = fathers' occupation; SCHTYPE = school type; SCHSEX = school sex; SCISUBS = science subjects; INTRCPT = intercept; t-ratio = estimated coefficient/standard error.

The fixed effects panel in Table 9.6 shows t-ratios and p-values for school type (SCHTYPE), school sex (SCHSEX) and status of student's father's occupations (FATOCC), which indicate that these variables should be included in the model. An interaction between school sex and student's father's occupation, which influences the dependent variable, is shown by the t-ratio and p-value. The t-ratio, 2.18, is greater than 2, and the p-value, 0.04, is small enough to indicate that this effect is not likely to have occurred by chance. None of the estimated level-2 coefficients in the final exploratory analysis of all potential level-2 predictors was large enough to explain further variance.

For this multi-level analysis, the overall effect of socioeconomic status (SES or the status of father's occupation) on student's expectation of further study of science was that students from higher status backgrounds had greater expectations of future science study at university than students from lower status backgrounds. These students from high socioeconomic status backgrounds also liked science more than students from lower socioeconomic status backgrounds, and this greater liking of science could also have resulted in increased expectations to continue with the study of science at university. The positive influence of high socioeconomic status backgrounds father's occupation on student's expectation of future science study and further education is indicated by the coefficient of -0.14 and the t-ratio of -4.9, since high status father's occupation is coded 1, and low status father's occupation, coded 6.

Like the findings for the examination of the effects of multi-level variables on student's liking of science, for the examination of the variables affecting student's expectation of future science study, there were different effects in different types of schools. An important effect shown by the positive sign of the school type effect (SCHTYPE) coefficient in this analysis, is that students in non-government schools had greater expectations than students in government schools for future science study at university and further education (government schools were coded as 0, and non-government schools 1). Interacting effects were obtained by analysing the influence of the socioeconomic status of father's occupation on the expectations of students in boys, girls, and coeducational schools of future science study. Figure 9.2 shows the interaction between school sex and father's occupation in terms of student's expectations of future science study.

Figure 9.2 shows that in boys schools and coeducational schools, students from backgrounds of higher status, in terms of SES level of father's occupation, have greater expectations of future science study at university and further education than students from backgrounds of lower status. However, the slope for girls' schools is so small that it shows that there is very little difference in expectations of future science study and further education in the comparison between students from high socioeconomic status backgrounds and students from backgrounds of lower socioeconomic status.



$Y = -0.45 + 0.35\ SCHTYPE - 0{,}14\ FATOCC + 0.23\ SCHSEX\ .FATOCC^{a} + r$

a: It should be noted that in the calculations of slopes the SCHSEX variable is centred around its grand mean

Figure 9.2 The influence of the interaction between school sex and father's occupation on the student's expectations to include science subjects in university studies

In the item, which sought information about students' expectations to continue with university studies, university study, which did not include science subjects, was rated as 2, while expectations to continue with university studies, which included science subjects, was rated as 3. Thus, these greater expectations of future science study at university of students from high status backgrounds in boys and coeducational schools result could be interpreted, in part, as an indication that students from high socioeconomic status backgrounds are more likely to attend university, whether or not these students study science.

A significant effect between the high socioeconomic status of a student's father's occupation and the student's expectation to continue with university studies which include science subjects, might be a consequence of the student having a greater opportunity to pursue university study of any kind, since there is likely to be less financial impediment to university studies. This financial concern in expectations for further study and careers of students in the different school types was further evidenced by the consideration that the number of years required to complete a law degree or a medical degree, and therefore the cost, is greater than for a science degree.

Parents with higher socioeconomic status occupations might be more able to support their offspring in these professional courses than parents from occupations of lower socioeconomic status.

Model of the Contribution of the Variables at Both Levels

The results of multi-variate analysis for the school-level and student-level variables in each analysis are summarised in Table 9.7. The level-1 variable, father's occupation (FATOCC) was significant in explaining all five of the outcome variables, and sex of student is significant in the explanation of liking science, as well as the coherence of students' STS views on the *Science* and *Scientists* scales.

The level-2 variables school type (SCHTYPE) and school sex (SSEX) were significant factors affecting the outcome variables liking of science (LIKSCI) and expectations of further study of science after the completion of secondary school (SCISUBS). For the examination of level-2 variables affecting the strength and coherence of students' views on STS, the only significant variable was average level of father's occupation for a school (SCHFOCC) on the *Science* scale.

At level 1 for the analysis with the outcome variable *Society*, student sex had no effect on the strength and coherence of students' STS views. However, the socioeconomic status of student's father's occupation was found to have an effect. The negative sign of the coefficient for father's occupation shows that students from backgrounds of high status had stronger and more coherent views on STS than students from backgrounds of lower status. The same effect of student's socioeconomic status or background was observed for both the *Science* and *Scientists* scales. The analysis on the *Science* and *Scientists* scale for the effects of sex of student demonstrated significant effects of the level-1 variable.

Table 9.7 Results of multi-variate analysis - t-values

t-values	**Student level**		**School level**		
	Fathers Occupation[a]	Sex of Student[b]	Intercept	Fathers Occupation Slope[c]	Sex of Student Slope
Society	-3.41	*	*	*	*
Science	-4.01	2.17	-2.44 (SCHFOCC)	*	*
Scientists	-2.67	4.24		*	*
Like Science	-2.04	-4.09	3.35 (SCHTYPE)	1.71 (SCHSEX)	*
Science Subjects	-4.90	*	2.27 (SCHTYPE)	2.18 (SCHSEX)	*

a: negative sign represents high status is more favourable; b: positive sign represents girls views are more favourable; and a negative sign represents boys more favourable; c: positive sign represents girls more favourable; SCHFOCC = socioeconomic status of school; SCHTYPE = school type; SCHSEX = school sex; * = not significant and not entered into the equation

The positive signs of the coefficients for student sex shows that girls had stronger and more coherent views on STS on both of these scales, since boys were coded as 0, and girls were coded as 1. For the *Science* scale the level-2 variable SCHFOCC also had an effect, and the negative sign of the coefficient indicated that students from schools of high average socioeconomic status had stronger and more coherent views on STS on this scale than students from schools of lower average socioeconomic status.

The combined multi-level equations for outcome variables liking of science (LIKSCI) and expectations of further study of science after the completion of secondary school (SCISUBS) are more complex, since there are significant student-level factors (SSEX) and (FATOCC), a school-level variable (SCHSEX), and an interaction between variables (SCHSEX.FATOCC) influencing both of the outcome variables.

Summary

Students who are grouped in schools tend to take on the characteristics of the school group, and as a consequence the students in one school are more like each other than they are like the students in another school. This effect has not been provided for in traditional statistical analyses of educational data.

This error in viewing school effects in regard to student performance has been stressed by Bryk and Raudenbush (1992). Cross-level interactions necessitate models and techniques that specify how effects at each level influence processes that occur at other levels. Problems that could result when traditional methods are employed have been overcome in this study by using HLM/2L computer program (Bryk, Raudenbush and Congdon, 1994). Thus, the influence at both levels, of sex and the socioeconomic status of father's occupation, as well as the interaction between these variables on students' liking of science and future science study, have been investigated using HLM in this study.

First, the factors, which influenced the strength and coherence of students' STS views on the three scales, were investigated using HLM. Students from backgrounds of high socioeconomic status were found to have stronger and more coherent views on STS than students from backgrounds of lower socioeconomic status. On the *Science* and *Scientists* scales another level-1 variable, sex of student, was found to affect the strength and coherence of students' views on STS. Girls were shown to have stronger and more coherent STS views than boys on both of these scales. The only level-2 variable that was found to influence students' STS views on any of the three scales was the average socioeconomic status of school father's occupation. For the *Science* scale, students in schools with fathers on average in an occupation of higher socioeconomic status had stronger and more coherent views towards *Science* than students from backgrounds of lower status. School sex (SCHSEX) was significant with regard to liking of science and future science study. This level-2 variable was coded as an aggregated school variable, which is both appropriate and useful for this analysis.

The influence of father's occupation on student's liking of science was found to be interacting with school sex. In boys' schools, students whose fathers were employed in positions of higher occupational status liked science more than students with fathers who were employed in positions of lower occupational status. For girls' schools, however, the socioeconomic status of student's background was found to make very little difference in regard to students' liking of science. In coeducational schools, students from backgrounds of high socioeconomic status liked science more than students from backgrounds of lower status. The overall analysis of liking of science by students showed, however, that students from backgrounds of higher socioeconomic status, in terms of status of father's occupations, liked science more than students from backgrounds of lower status.

The socioeconomic status of father's occupation also interacted with school sex to influence student's expectation of future science study. In girls' schools, the status of student's father's occupation was found to have very little influence on the student's expectation of future science study. In boys schools and coeducational schools, by way of contrast, students from backgrounds of higher status of father's occupation had greater expectations to include science subjects in their university studies than students from backgrounds of lower status. However, this result could be interpreted, in part, as an indication that students from high socioeconomic status backgrounds are more likely to attend university, whether or not they study science.

The findings of this multi-level analysis using HLM/2L have substantial implications for both teaching and curriculum design in relation to the STS objectives of secondary science courses in South Australia. Both equity and efficacy in secondary science education in South Australian secondary schools would be facilitated by careful consideration of these findings.

Since in this study, the use of HLM showed significant effects for sex of student, in regard to views on STS, and sex of school was significant in regard to liking of science and future science study, it is useful to examine gender more carefully. The results from the HLM chapter merely summarise the effects of gender, and since this is a major concern for the provision of gender equity in access to science and technology in Australia, it warrants a more detailed examination using other procedures of analysis. This more detailed examination of the effects of gender is the topic of the next chapter.

10

Gender Differences

In most countries over the past 25 years, the achievement of boys in senior secondary science education has continued to surpass that of girls, although there is evidence that the gap is being reduced, particularly in Australia (Comber and Keeves, 1973; Keeves, 1992a). In view of this change, a significant educational development in South Australia over the past five years has been instituted through the inclusion of STS objectives in senior secondary science curricula. This development provides a unique opportunity to investigate gender differences in students' views towards STS. In order to provide for gender equity in access to secondary science education in science and technology, the question of whether this educational development has helped to support the reduction of gender differences in views concerning science at the senior secondary school level in South Australia is considered in this chapter.

Research on Gender Differences

There has been a substantial body of published research on gender differences in relation to performance in science over the past 25 years. Discussion of this research constitutes the first section of this chapter on gender differences in relation to STS. This research has investigated issues, which range from the origin of differences in educational achievement, to gender differences in conceptual and learning styles.

Gender Differences in Educational Achievement in Science

The First IEA Science Study was conducted by the International Association for the Evaluation of Educational Achievement (IEA) in 1970-71, across 19 countries. This study established the existence of effects associated with the gender of the student on both attitudinal and achievement outcomes in science (Comber and Keeves, 1973). Gender differences in achievement in science education between 1970 and 1984 were also reported, across ten countries, following the completion of the Second IEA Science Study in 1983-84 (Keeves, 1992b). The differences between the sexes in science achievement increased with age from the primary to the lower secondary and then to the upper secondary school levels, and were greater in Physics than in Chemistry, which was greater than in Biology.

Although the pattern of results from the second study was similar to that of the first science study, there were overall reductions in the differences between the sexes in science achievement over time. In all fields of science and at all levels, however, male students continued to surpass female students in science achievement (Keeves, 1992a), although the magnitude of the difference decreased over time, particularly in those countries where vigorous programs to reduce the gender gap had been mounted.

Furthermore, evidence from simultaneous analyses in the second study of achievement in science in 1983-4 indicated that similar processes operated for boys and girls in the influence of attitudes upon achievement in science (Johnson, 1995). Johnson (1995) chose to analyse the same data separately and more extensively for boys and girls and showed some differences between the sexes in the processes that operated.

The Origin of Gender Differences in Educational Achievement

The view that explains girls' under-achievement in science in terms of social factors (Kelly, 1981; Manthorpe, 1982; Keeves and Kotte, 1992), has received far greater support from studies conducted in the past 20 years than the hypothesis advanced by Gray (1981) that the differences were due to biological factors. Under the culture hypothesis, the relatively poor achievement of girls in science was attributed to social or cultural factors. Consequently, girls did not achieve as well in science as boys did, largely because society did not expect them to do as well.

Achievement by females in science has not been sufficiently encouraged or recognised over the years. Instead, an image of females as occupying supportive roles in society, with respect gained for vicarious achievement through their husbands and children, has resulted in girls fulfilling society's expectations of them and under-achieving in science. This image of females' role in society has been supported by the media and in children's literature (Kelly, 1981).

It has been suggested that although there were differences between the sexes in ways of thinking, neither sex was inferior in cognitive ability (Gilligan, 1982). The author described females' thinking as domestic, since females made decisions as to what action might do less hurt to people (Gilligan, 1982). Gilligan also suggested that a great injection of females' ways of thinking was necessary for correct social decision-making. This suggestion is relevant to this present study, since the inclusion of STS in senior secondary science curricula necessitates consideration of social decision-making.

The Possible Causes of Girls' Under-achievement in Science

It is important to examine further research findings relating to the possible causes of girls' under-achievement in science, since an understanding of the possible causes could help to identify measures to reduce the differences between the sexes in educational achievement. Some of the research in this area has focused upon gender differences in thinking about social and moral issues. Studies by Gilligan (1982), Manthorpe (1982) and Head and Ramsden (1990), by way of example, have linked girls' under-achievement in science to: (a) a preference for learning situations which involved friendship groups; (b) gender differences in thinking in relation to values and morals; and (c) the need for girls to be provided with learning strategies which allowed sufficient time and information to consider all possibilities before making decisions.

In addition to lower overall achievement in science, there were fewer females than males choosing to study science in Australia in the early 1990s. Unfortunately, the sex stereotyping of science subjects from quite an early stage of secondary education led to a smaller number of females than males in secondary science classes. A study in Western Australia by Rennie and Parker (1993) reported interesting changes in the science enrolment and achievement patterns of males and females as a result of lowering the age for subject choice in secondary schools. This Western Australian study in 1987-1990 aimed to investigate the consequences of the curriculum innovation, the Unit Curriculum, in regard to equitable participation and achievement in science. This system-wide change at the lower-secondary level involved repackaging the curriculum into units. From these units students selected combinations to study during the year. However, Rennie and Parker found that the unfortunate consequence of this curriculum change was that time spent in the study of science was reduced, particularly for girls. The authors concluded that:

> Although no causal relationship has been established by this research, it appears that greater freedom of subject choice for 13- to 15- year-old students is associated with a pattern of choice characterised by less science, and by early and explicit sex stereotyping of science disciplines. (Rennie & Parker, 1993, p. 1026)

Gender Differences in Conceptual and Learning Styles

A powerful admonition of what is called ‘elite science’, which did not emphasise the social relevance, or make the topics more relevant and interesting for girls was advanced by Parker (1992). Parker suggested that formerly, science was designed for an elite, mostly male group. Thus, it was considered necessary to redesign science curricula to cater for gender differences in conceptual and learning styles.

Over the past 21 years there have been a substantial number of articles on the different learning styles of girls and boys. As early as 1975, Ormerod and Duckworth reported gender-based differences in learning, and suggested that girls and boys responded differently to various teaching strategies. The Australian authors (Head and Ramsden, 1990) in a paper on gender, psychological type and science wrote that gender-linked cognitive differences were not in abilities, but more in learning styles or conceptual styles. The inference was made that these learning styles influenced the subject choices made by girls. This preference for particular learning styles, as well as for particular curriculum emphases, was demonstrated in a study, which involved emphasising the social and applied importance of the physics topics to make the topics more “girl-friendly”. The result of making the science more relevant to humanistic concerns was that more girls opted for the science subject (Head and Ramsden, 1990).

Further evidence of the differences in learning styles of male and female students was provided by Copeland (1995), who found that most of the female engineering students involved in her study at the University of Adelaide were conscious of differences between the learning styles and attitudes of males and females. This finding is significant for this present study in which differences in attitudes and views were measured. One of the differences suggested by the female students was the concern that females showed for the social context of their work. By way of example, one of the students said that:

> We seem to have opposite ways of thinking from the guys. We did a project (solar car race) with some guys and they were putting down aims of the project like “finish the race” and things like that but they didn’t think about things like involvement of the university and the outlook for the community. We were thinking different things. (Copeland, 1995, p. 12)

In South Australia, the project, *Femininity and Reality*, took up the task, in 1989, of exploring the factors that affected girls’ learning. The project was undertaken by the Education of Girls Unit of the South Australian Education Department. It was considered that schools had dealt inadequately with practices and attitudes influencing the lives of adolescent girls. Adolescent girls were articulate about the dilemmas they faced, but they said that schools were not dealing adequately with those dilemmas (Hyde, 1992).

The situation appeared to be even more critical for aboriginal girls, girls of non-English speaking backgrounds and those from backgrounds of low socioeconomic status (Hyde, 1992). The barriers that affected the learning of many girls from a different country included language differences, class-bound values, culturally-bound values, stereotyping, and past experiences both positive and negative. However, the experiences of these girls might have given the girls an understanding of issues such as the role of cultural values in family life and in society in general (Loro, 1992). Such understandings could be re-directed so as to be of greater benefit to classroom activities in STS, thereby catering for gender differences and providing greater equality in science education.

Ways Adopted for Addressing Gender Imbalance

The need to provide for equity of access to effective science education in Australia was supported in a recent report by the National Board of Employment, Education and Training (NBEET). Furthermore, attempts to ensure that students were provided with a curriculum that was inclusive of the experiences of all groups as a basic step towards addressing equity considerations were also supported (NBEET, 1994). The National Board also recommended that subject matter that reflected and expanded the interests of girls should be chosen for science classes. The inclusion of STS in science curricula in Australia addresses gender imbalance in access to effective science education by presenting a more human and socially relevant form of science. This depiction of science is more interesting, meaningful, and motivating for all students, but especially for girls.

STS to Reduce Gender Imbalance by Motivating Girls

A substantial body of research has investigated the inclusion of discussion of STS issues in science classes as a motivator, particularly for girls. Zoller et al. (1990) contended that their research indicated that the STS response profile was, with respect to some STS issues, gender-dependent. Although not all of the students were clear about the different roles of science and technology in society, important goals of the STS course were met by the students who were described by their teachers as 'non-academics'.

It appears that this response to the STS emphasis of the curriculum depended upon both social factors and the way in which the content was delivered. In England, the *Discussion of Issues in School Science* (DISS) study in 1988 aimed to explore how 17-year-old students used knowledge when they argued about science-based social issues presented in television programs that they watched in science lessons. Group discussion of STS issues was also evaluated (Solomon, 1992). Although some gender differences were evident in discussions, they were not as substantial as indicated by the research literature. Girls were motivated by this presentation of the social relevance of science.

The DISS study led to the conclusion that social factors brought about an exchange of perspectives which blurred gender differences and enabled group discussion to be a valuable educational experience for both boys and girls. During these discussions of science-based social issues, both boys and girls used the social circumstances or relevance of science to make links that assisted their understanding of scientific concepts. The need to consider other perspectives and the questions and comments of peers also contributed to the blurring of gender-related orientations (Solomon and Harrison, 1991). Education in STS using group discussion of issues might, therefore, be a way of achieving greater equality between the sexes in the outcomes of science education.

Research has also indicated that one way of addressing gender imbalance in access to effective science education, by making science more meaningful to girls, is to include consideration of the issues of STS in science classes. The *Girls into Science and Technology* (GIST) project in the United Kingdom, by way of example, was a research project with the aims of investigating the causes of female under-achievement in science and technology, with an attempt being made to remedy the situation. The GIST report suggested that among the causes of girls' under-achievement was the absence in science studies of social or human applications (Whyte, 1986).

When science materials were written in the past, too few links were made with the social, industrial and human applications of science in everyday life, to maintain the interest of girls. Girls were more interested in science if they learnt something of the useful and beneficial social applications of science. Moreover, Whyte (1986) has written that such socio-political issues as the impact of science on the environment seemed to be of special interest to girls. Whyte believed that girls' special interest in STS issues might have been seen as a reflection of their initial pre-disposition to be people-oriented rather than thing-oriented, or it might provide evidence of greater maturity and social responsibility on the part of young teenage girls compared with their male peers.

The importance of emphasising the social relevance of science was also upheld by Head (1987) when he suggested that science was frequently presented as though it had nothing to contribute to debates on important social issues, and seemed to be of little consequence for these important issues in people's lives. This impersonal representation of science was not attractive to students who were at a stage of their moral development when they were likely to be concerned with a variety of these complex social issues involving their future careers and life styles, ideologies, their emerging sexuality and the meaning of life (Head, 1987).

An alternative, more sociological and structural approach to science teaching would accommodate girls' characteristics to a greater extent than the traditional approach to science teaching. In this alternative approach, science would be presented as a socially constructed body of knowledge since it was produced in accordance with social norms (Kelly, 1987). The curriculum content of the traditional science courses therefore needed to change or be re-organised to fit girls' interests to a greater extent in order to remove some of the gender imbalance of traditional secondary science courses.

This consideration of the need to provide for greater equity in science education by presenting science in a relevant social context was further developed by Manthorp (1982), when she considered certain components that featured in a feminine view of science. These components included: (a) the involvement of social, ethical and moral questions; (b) respect for knowledge that might have a subjective component; and (c) the belief that the quality of life had priority over economics (Manthorp, 1982).

STS for a More Human Approach to Science

It has been suggested in this chapter that nurturative characteristics, such as interest in humans and concern for not harming others, have been characterised as products of the moral development of females (Manthorp, 1982; Whyte, 1986). Subsequently, Smail (1987) maintained that the curriculum should change to emphasise the human aspects of science as well as the social implications of science. It is significant for the purposes of this work that Smail supported her claims with statements of curriculum aims in relation to STS. These statements suggested that secondary school students should be provided with opportunities to:

1) study key concepts that are essential to an understanding of the part that science and technology play in post-industrial and technological society; and
2) appreciate that technologies are expressions of the desire to understand and control the environment and that technologies change in response to social needs. (Smail, 1987 p. 80)

As a consequence, it appears that females' liking of science might be increased by a more human approach to science.

This need for a more intensely human approach to science and technology was also identified by Polanyi (1964) when he argued that interpretations of nature were based upon intuitive perceptions. Hence, scientific discoveries had a personal component. Head and Ramsden (1990) also contended that there was a need to make science more relevant to humanistic concerns in order to enhance girls' ability to compete in the historically male-dominated domain of science. This identified need has far-reaching implications for science teaching.

Changes for Females in Australian Society

Assertions made about the relative nurturing and maternal protection of boys and girls do not hold true in the current social situation. Work expectations of mothers and of female members of society, in general, have changed greatly even in recent years. Keeves and Kotte (1992) wrote that between 1970 and 1984 there were significant changes in society in most countries, including Australia, which enabled females to participate for longer periods in the labour force and also led females to undertake more education and occupational training, in general, than was previously possible. The evidence suggests that, in recent years, there have been significant changes in the roles of females in society, with greater involvement in employment outside the home (Keeves and Kotte, 1992).

Valuing Females' Perspectives and STS Attitudes

It would be expected that this increased involvement in employment outside the home should have resulted in some change in the emphasis given to the caring perspective commonly found among females, for example, in the tertiary education system. This might have encouraged more females to pursue careers in areas involving science and technology.

Girls' underachievement in science and technology was previously linked to social attitudes towards the roles of females in the workplace, the home and in educational establishments (Kelly, Whyte and Smail, 1987). Fortunately, there has been a great deal of research, developmental work and publicity in recent years in Australia, which has resulted in a significant transformation of these social attitudes and expectations. These new understandings have helped to overcome traditional stereotypes, and there is now greater equity in career and educational opportunities for females in science and technology.

Improved Science Performance by South Australian Girls

The argument that gender differences in educational outcomes are a result of social or environmental influences and are not biologically based, coupled with the provision of greater equity for females in science and technology, would appear to explain the significant changes in observed educational outcomes between the 1970s and 1984 (Keeves and Kotte, 1992). An Australian study on sex bias in scholastic aptitude testing reported that sex differences in educational performance arose from "differences in socialisation for males and females" (Adams, 1984, p.5), which resulted in differences in career expectations and expectations of academic success, as well as in attitudes and values.

Changes over time in the participation and performance in educational achievement of South Australian boys and girls in the different Year 12 science subjects between 1989 and 1997 are shown in Table 10.1. The figures for relative participation of male and female students in both publicly examined Biology and school-assessed Biological Science remained fairly constant, although there was a slight decrease in the ratio of male to female Biological Science students between 1993 and 1995. There was a rise in the participation of female students in Physics from 1989 until 1993, which is shown as a decrease in the male/female participation ratio for this period. The subsequent increase in the male/female participation ratio was only for one year, after this the relative participation of male students compared with female students in Physics continued to fall again from 1994 to 1997. Thus for Physics there was an overall increase in the participation of female students compared with male students in 1989-1997. For Chemistry, the rises and falls in retention and participation rates have been slightly smaller, but there was also an increase in the participation of female students compared with male students of Chemistry during this period from 1989-1997.

Consideration of these data, in the light of the need discussed above to provide for equity of access to effective science education for all groups (NBEET, 1994), reveals the need for further discussion of ways in which to make the curricula of senior secondary science subjects more inclusive of all groups. Parker's (1992) finding that the design of the former science curricula favoured males, and the views that there were relationships between social factors and girls' underachievement in science (Kelly, 1981; Manthorpe, 1982; Keeves and Kotte, 1992) also point to the need for further study and discussion of factors affecting the differences in learning outcomes between the sexes. With the change in social and professional roles, including academic expectations and opportunities for females in societies, it is anticipated that gender differences in educational outcomes in science should further decrease.

The Australian Science Teachers Association's study on factors affecting students' understanding of science at the beginning of secondary school found no overall difference in performance between males and females on the concept and skill items. The study did, however, find that overall, on the items, which concerned attitudes to science, males' opinions were expressed more strongly, and a greater proportion of females' responses were in the undecided category (NBEET, 1994). Moreover, a former study found that more girls chose to study science when the human side of science was emphasised (Head and Ramsden, 1990). Discussions of STS issues demonstrate the human side of science. Differences in the profile of views towards STS gauged by responses to statements on STS in the present study, have the potential to guide the development of more inclusive science curricula.

Thus, the importance of investigating whether the STS response profile is gender-related is highlighted by factors which include: (a) the different expectations and opportunities for females which are discussed above; (b) the new secondary science curricula in South Australia which include STS objectives; and © the need to emphasise the "human face" of science in discussions in science classes to make the curricula more inclusive of both sexes.

Table 10.1 Participation over the years 1989 to 1994 in Publicly Examined Subjects (Physics, Chemistry and Biology) and the School Assessed Subject, Biological Science, for female (F) and male (M) students

	Total		Grand Total	% a		Ratio b
	Female	Male		Female	Male	M/F
Physics						
1989	1020	2543	3563	9.29	21.77	2.34
1990	1021	2451	3472	10.11	22.95	2.27
1991	1097	2514	3611	11.48	23.90	2.08
1992	1322	2846	4168	14.11	28.61	2.03
1993	1222	2503	3725	13.55	26.04	1.92
1994	1009	2149	3158	11.42	23.41	2.05
1995	935	1788	2723	11.21	20.33	1.81
1996	881	1693	2574	10.77	19.32	1.79
1997	982	1779	2761	11.44	19.62	1.72
Chemistry						
1989	1222	2094	3316	11.13	17.93	1.61
1990	1225	1993	3218	12.13	18.66	1.54
1991	1231	1984	3215	12.88	18.86	1.46
1992	1408	2144	3552	15.03	21.56	1.43
1993	1343	1910	3253	14.89	19.87	1.33
1994	1176	1684	2860	13.31	18.34	1.38
1995	1079	1376	2455	12.93	15.65	1.21
1996	1038	1264	2302	12.69	14.43	1.14
1997	1106	1382	2488	12.88	15.24	1.18
Biology						
1989	3343	1960	5303	30.45	16.78	0.55
1990	3226	1907	5133	31.93	17.86	0.56
1991	3488	2189	5677	36.50	20.81	0.57
1992	3757	2400	6157	40.10	24.13	0.60
1993	3406	2143	5549	37.77	22.29	0.59
1994	2947	1783	4730	33 36	19.42	0.58
1995	2534	1508	4042	30.37	17.15	0.56
1996	2741	1504	4245	33.50	17.17	0.51
1997	2816	1500	4316	32.80	16.54	0.50
Biol Science						
1989	1217	633	1850	11.09	5.4	0.49
1990	1296	720	2016	12.83	6.74	0.53
1991	1592	937	2529	16.66	8.91	0.53
1992	1682	981	2663	17.95	9.86	0.55
1993	1619	918	2537	17.95	9,55	0.53
1994	1466	740	2206	16.59	8.06	0.49
1995	1010	508	1518	12.11	5.78	0.48
1996	593	322	915	7.25	3.67	0.51
1997	430	252	682	5.00	2.78	0.56

a: total number of male or female students expressed as a percentage of the original Year 8 male or female cohort of that Year 12 group of students;

b: male/female participation ratio.

Biol Science: SAS Biological Science

Data taken from the annual reports of the Senior Secondary Assessment Board of SA for 1989 to 1997 and Australian Bureau of Statistics, 1985-1990 (original cohort).

One group of results referred to as 'partial assessment' or results for students who present only a school assessment or an examination assessment are not shown above.

Differences Between the Sexes in Views on STS

The results of the examination of gender-related differences in the STS response profile of Year 12 students in South Australia are discussed in this section.

Gender Specific Responses to Items on STS Issues

Table 10.2 shows a substantial number of significant differences in gender-specific responses to STS issues in 18 of the 27 Items. In Chapter 5 it is argued that, for a relationship to be considered significant, it is necessary for the χ^2 value to exceed a specified critical value. For some of these questions it was possible, with further statistical calculations, to identify an area of significance.

Table 10.2 Items with a significant gender-based relationship

Item number and topic	χ^2 a	Cri val[b]	Area of significance (sign.)
1. Science and technology to solve practical problems	23.3	16.9	Not possible to work out
3. Government funding of research to explore curious unknowns of nature and universe	25.0	15.5	Not possible to work out
4. Discoveries made by male and female scientists	43.8	21.0	Response: any differences in their discoveries are due to differences between individuals.
5. Students to study more science at school as the success of science and technology depends on having good scientists	23.5	18.3	Not possible to work out
6. Community and government agencies to tell scientists what to investigate	17.0	16.9	Not possible to work out
11. Best scientists follow the scientific method	15.8	14.1	Not possible to work out
13. The reason for more male than female scientists in Australia today	76.2	18.3	Response: males are stronger, faster, brighter and better at concentrating on their studies
15. Corporation control of science	22.1	15.5	Not possible to work out
16. Scientists and engineers should make the decisions on Australia's energy future, as they know the facts best	27.9	16.9	Not possible to work out
18. The best scientists have personal characteristics such as logic, open-mindedness, objectivity and lack of bias	29.0	15.5	Response: it depends on the individual scientist.
19. The effect of politics on Australian scientists	17.5	16.9	Not possible to work out
20. Differences between male and female scientists - scientific method females/males	34.0	19.7	Response: any differences in the way scientists do science are due to differences between individuals.
21. Success of science and technology depends on public support - ie on high school students learning science	21.5	14.1	
22. Technology improves living standards	41.6	15.5	Response: the quality of living may improve, but the quality of life may not
23. Scientists choosing to do military research	25.4	14.1	Not possible to work out
24. Science and technology to fix pollution problems	24.0	15.5	Not possible to work out
25. Scientific advance under government control	14.1	14.1	Not possible to work out
27. Australian scientists' motivation for doing science	37.6	18.3	Not possible to work out

a: χ^2 values were adjusted for cluster sampling by division by an estimated design effect of 2

b: critical values

The area of significance for a particular item involved the response that contributed to the significant relationship. The original χ^2 values were divided by two, which is an estimation of the design effect for between sex comparisons within schools. Significant effects associated with a particular response were identified by comparing the diff-erences in percentages between groups using the nomographs in Oppenheim (1992).

The detailed discussion of the method for establishing whether an item had a significant gender-based relationship is discussed in Chapter 5, and is only outlined briefly here. For the χ^2 value for a particular item to show a significant gender-based relationship, it has to exceed the appropriate critical value in the Table of Critical values of χ^2 for the specified degrees of freedom at particular percentage levels.

The response that contributed to the significant correlation was then established using the nomograph. It was possible to locate a significant response difference for Items 4, 13, 18, 20 and 22. In Item 4, which sought students' views on whether scientific discoveries made by females were different from those made by males, the significance was identified to arise in response G. Response G stated that there were no differences between male and female scientists in the discoveries they made, because any differences in their discoveries were due to differences between individuals, which had nothing to do with being male or female. This response, which was made by a significantly greater number of girls than boys, had the high scale value of four.

There was also a significant gender-based relationship for Item 18, since a significantly greater number of female than male students chose response E. This response involved the statement that the best scientists did not necessarily display personal characteristics such as open-mindedness, logic, and objectivity in their work, since this would depend on the individual. Some scientists displayed these characteristics, while others became closed- minded and subjective in their work.

Students' views on differences between male and female scientists in terms of the methods used in their scientific work were sought by Item 20. In a way, which was similar to Item 4 and Item 18, for Item 20, the choice of response F by a significantly greater number of females than males emphasised the human face of science. In Response F it was stated that any differences in the way scientists did science were due to differences between individuals, which had nothing to do with being male or female.

For Item 13, by way of contrast, a significantly larger number of males than females chose response 1, that the main reason there were more male scientists than female scientists in Australia was that males were stronger, brighter, faster and better at concentrating on their studies than females. It is of interest that the significance for this item was particularly marked, since this response reflects substantial gender bias by some male students.

The first four items where the areas of significance were identified, as discussed above, were all concerned with the characteristics of scientists. However, Item 22, in which a significant difference between the responses of male and female students was also identified, involved the statement that technology would improve the standard of living for Australians. The belief that more technology would make life easier, healthier and more efficient, but would cause more pollution, unemployment and other problems, formed the basis of response E. This response, which was chosen by more females than males, stated the view that the standard of living might improve, but the quality of life might not.

Clusters of items where there were significant differences between the responses of male and female students and the issues with which they were concerned included:

1) Items 3, 6, 15 and 25 relate to the funding and control of science.
2) Items 11 and 18 relate to the characteristics of the best scientists and the method used by these scientists.
3) Item 16 relates to the role of scientists and engineers in energy decisions.
4) Item 19 relates to the influence of politics on scientists.
5) Item 1 relates to the use of science and technology to solve practical problems.
6) Items 5 and 21 relate to whether students should be required to study more science at school.
7) Items 4, 13 and 20 relate to the characteristics of male and female scientists.
8) Items 22 and 24 relate to the capacity of science and technology to solve problems.
9) Item 27 relates to the motivation of Australian scientists for doing science.

These responses with gender-based differences are fairly evenly drawn from across the three scales with seven items from the *Society* scale, six items from the *Scientists* scale, and five items from the *Science* scale. It is important to note, however, that the items (Items 4, 13, 20 and 27), which have a particularly high χ^2 value, relate to the human element of science, in terms of the characteristics and choices of scientists. This appears to support statements from the literature, discussed later in this chapter, that females are person-oriented, and consequently achieve a greater understanding of science courses taught from this perspective.

Sex Differences Between Students and Between Schools in Views on STS

Some differences between students in their STS views were expected, since previous research studies have shown that while at both the upper and lower secondary school levels there have been overall reductions in the sizes of the differences in the achievement in science between 1970-71 and 1983-84 (Keeves, 1992a), recognisable differences still remained. However, Head and Ramsden (1990) have suggested that the effective inclusion of discussion of STS issues in science courses contextualises science to provide motivation for female students and this should lead to greater understanding of STS issues by females.

As well as the presence of sex differences in educational outcomes between students, it is important to investigate sex differences in educational outcomes between schools of different types (single-sex or coeducational schools). A previous Australian study (Marsh, 1989), found that students' achievements, attitudes and behaviours were not affected by attending single-sex or coeducational high schools. In the analysis of sex effects in this present Australian study, both HLM and WesVarPC were used to enable valid conclusions to be formulated with regard to sex differences between students and between schools. The analysis was first performed with WesVarPC to see if any differences could be detected at the student level, across all schools in the sample. HLM was then used to determine whether there were any significant effects at either the macro- (school) level or the micro- (student) level. An explanation of the purposes and methodology of HLM is presented in Chapter 9.

Gender Differences in STS Views and Understandings

It was considered important in this study to examine if there was a relationship between gender and the strength and coherence of students' views on STS. Table 10.3 shows the results on the three scales and the effect sizes of the differences between the STS views of male and female students on the three scales for the analysis performed with the WesVarPC program (Brick et al, 1996). WesVarPC only became available at a late stage in the preparation of this work and has not been used in all possible analyses. The standard errors were calculated using a jackknife procedure, in order to allow for the cluster sampling of the data.

Table 10.3 Sex differences in students' views of Society, Science and Scientists

Group	N[a]	t-ratio	p-value	Mean	se[b]	sd[c]	Differ[d] (se)	Effect Size[e]	Effect[f] Size Category
Society	1276	1.84	0.033	0.21	0.028	0.59	0.08 (0.046)	0.14	Trivial
Male (M)	647			0.17	0.039	0.62			
Female (F)	629			0.25	0.032	0.56			
Science	1276	4.08	0.000	0.32	0.033	0.55	0.16 (0.040)	0.29	Small
Male (M)	647			0.24	0.038	0.57			
Female (F)	629			0.40	0.036	0.52			
Scientists	1276	6.18	0.000	0.41	0.032	0.58	0.24 (0.037)	0.41	Small
Male (M)	647			0.29	0.036	0.58			
Female (F)	629			0.53	0.032	0.56			

a: number; b: jackknife standard error of mean; c: standard deviation; d: difference female mean-male mean; e: effect size obtained by dividing the difference between the two groups by the combined standard deviation; f: for effect size classification see Chapter 5 and Cohen (1969, p. 25).

A positive effect size shows that female students held stronger and more coherent views on STS than male students. On all three scales, the mean scores for females for views on STS are larger than the mean scores for males.

There are statistically significant differences between the sexes shown in Table 10.3 on the *Society*, *Science* and *Scientists* scales. A statistically significant difference between the sexes for the strength and coherence of students' views on STS for the *Society*, *Science* and *Scientists* scales is shown by p-values <0.05. The effect sizes were obtained by dividing the difference between the mean scores of the two groups by the combined standard deviation. The rule for assessing the effect size category was: large effect size >0.8; medium effect size >0.5; small effect size >0.2, and trivial effect size <0.2 (Cohen, 1969). The effect size categories with this system of classification for the relationship between gender and coherence of students' views are small for both the *Scientists* scale and the *Science* scale. The important feature of these results is that on each of the three scales the girls showed stronger and more coherent views on STS issues than did the boys.

Society Scale

The results of the multi-level analysis of the effects of sex at both the micro- and macro-levels for differences in the strength and coherence of students' views on STS on the *Society* scale are shown in Table 10.4(a). There are no significant sex effects on the strength and coherence of students' STS views on the *Society* scale at either the macro- or the micro-level. At the micro-level this is indicated by a t value for SSEX slope G_{10} (0.413) that does not exceed 2.0 and has probability that is larger than 0.05.

Table 10.4a Results from the multi-level analysis of the effects of sex with outcome variable Society

Final estimation of fixed effects:

Fixed Effects	Coefficient	se	t-ratio	p-value
INTRCPT 1, B_0				
INTRCPT 2, G_{00}	0.325	0.082	3.950	0.001
SCHSEX, G_{01}	0.044	0.114	0.391	0.698
SSEX slope, B1				
INTRCPT, G_{10}	0.021	0.051	0.413	0.682

Reliability estimates Intercept 1, B_0 = O.533, SSEX, B_1 = 0.516

Final estimation of variance components:

Random Effect	Standard Deviation	Variance Component	df	χ^2	p-value
INTRCPT 1, U_0	0.304	0.093	23	61.37	0.000
SSEX slope, U_1	0.186	0.035	24	57.93	0.000
level-1, r	0.518	0.269			

se = standard error; SSEX = sex of student; SCHSEX = sex of school; INTRCPT = intercept; t-ratio = estimated coefficient/standard error.

Science Scale

Table 10.4(b) shows the results of the multi-level analysis for differences in the coherence of students' views on STS on the *Science* scale. The final estimation of fixed effects in Table 10.4(b) shows that there is a significant student sex effect, since the t value for the micro-level effect of SSEX slope (G_{10}) is greater than 2 and the probability is less than 0.05.

Table 10.4b Results from the multi-level analysis of the effects of sex with outcome variable Science

Final estimation of fixed effects

Fixed Effects	Coefficient	s e	t-ratio	p-value
INTRCPT 1, B_0				
INTRCPT 2, G_{00}	0.282	0.080	3.540	0.002
SCHSEX, G_{01}	-0.011	0.132	-0.084	0.935
SSEX slope, B1				
INTRCPT, G_{10}	0.120	0.051	2.340	0.027

Reliability estimates Intercept 1, B_0 = O.495, SSEX, B_1 = 0.510

Final estimation of variance components:

Random Effect	Standard Deviation	Variance Component	df	χ^2	p-value
INTRCPT 1, U_0	0.282	0.080	23	45.60	0.004
SSEX slope, U_1	0.185	0.034	24	49.89	0.002
level-1, r	0.522	0.272			

se = standard error; SSEX = sex of student; SCHSEX = sex of school; INTRCPT = intercept; t-ratio = estimated coefficient/standard error.

Likewise at the macro-level, the variable SCHSEX (G_{01}) which distinguished between the single sex boys' and girls' schools and the coeducational schools on a scale ranging from 1.00 (boys' schools) to 2.00 (girls' schools) showed a t-ratio (0.391) that indicated no significant effects.

Scientists Scale

Table 10.4(c) shows the results of the multi-level analysis for differences in the coherence of students' views on STS on the *Scientists* scale. In a way, which is similar to the analyses for the *Science* scale, for the *Scientists* scale there is a significant difference between the strength and coherence of the STS views of girls and boys, with girls expressing stronger and more coherent views on STS than boys with respect to the *Scientists* scale. The coefficient of SSEX slope (G_{10}) at the micro level has a t value of 3.37, which is clearly significant. However, at the macro-level the t-ratio coefficient of SCHSEX (G_{01}) is 0.52 and is clearly not significant although positive with students in girls' schools expressing only slightly stronger and more coherent views than students in boys' schools, after effects at the micro-level have been taken into consideration.

The inclusion of STS objectives has been the most recent change in the secondary science curricula in South Australia. Examination of the data from the present study indicated that there were no significant differences for type of school whether single sex or coeducational in regard to the coherence of STS views on any of the three scales. Nevertheless, there were significant differences between the STS views of girls and boys on the three scales using analysis of variance with SPSS and WesVarPC. With HLM, significant differences between the sexes in views on STS were found for the *Science* and *Scientists* scales. The findings of the study with regard to student sex support the findings in the literature, which have suggested that the inclusion of STS objectives in secondary science curricula might provide girls with relevance and motivation, thereby helping to address the differences between the sexes in science achievement and possibly interest.

Since boys were coded as one and girls as two, the positive coefficient (0.120) for SSEX (G_{10}) slope shows that girls had more coherent views on STS than boys.

Table 10.4c Results from the multi-level analysis of the effects of sex with outcome variable Scientists

Final estimation of fixed effects:

Fixed Effects	Coefficient	s e	t-ratio	p-value
INTRCPT 1, B_0				
INTRCPT 2, G_{00}	0.146	0.063	2.31	0.029
SCHSEX, G_{01}	0.044	0.085	0.52	0.611
SSEX slope, B1				
INTRCPT, G_{10}	0.133	0.039	3.37	0.003

Reliability estimates Intercept 1, B_0 = O.320, SSEX, B_1 = 0.300

Final estimation of variance components:

Random Effect	Standard Deviation	Variance Component	df	$\chi 2$	p-value
INTRCPT 1, U_O	0.180	0.032	23	34.84	0.054
SSEX slope, U_1	0.010	0.00009	28	32.76	0.109
level-1, r	0.494	0.244			

se = standard error; SSEX = sex of student; SCHSEX = sex of school; INTRCPT = intercept; t-ratio = estimated coefficient/standard error.

However, as is found in the analyses for the *Society* scale, there is no significant effect for SCHSEX (G_{01}) at the macro- (school) level for the *Science* sale, since at the school-level the t-ratio is -0.084 and the probability value for school sex is >0.05. The negative coefficient of the macro level indicates that there is a tendency for students in the boys' schools to express stronger and more coherent views about *Science* than for students in girls' schools after the effects at the student level have been provided for. However, this school effect is very slight.

Factors Affecting Girls' Progress in Science in Australia

Analysis of statistics relating to public examinations for students aged 16-plus in Britain led Harding (1981) to contend that for science subjects, girls in single-sex schools were more successful than girls in coeducational schools of equivalent socioeconomic type and boys were more successful than girls in coeducational schools.

The issues, which involve girls' success in single sex schools in relation to the success of girls in coeducational schools, have included:

(a) the relative numbers of students choosing science and technical subjects; and

(b) the effects of the environment of single sex and coeducational schools on girls' confidence and vocational motivation towards the study of science (Byrne and Hazel, 1992b).

The findings of other research studies into gender differences, which are related to success in the study of science, have highlighted the importance of gender differences in the liking of science and expectations to include science subjects in further education (Lee and Bryk, 1986; Marsh, 1989; Lee and Bryk, 1989; Marsh and Rowe, 1996a).

On the basis of these research findings, it would be expected that in different types of schools, girls' choices to continue with the study of science and their liking of science might be influenced by the desire to gain approval from or not having to compete with boys. It is, therefore, important to consider the effect of single-sex or coeducational schools on girls' and boys' liking of science and further study of science subjects.

In this present study, the effects of student sex and school sex on students' liking of science as well as students' expectations to include science subjects in further study after the completion of their secondary studies were analysed using both WesVarPC and HLM. The variables for the HLM runs were dummy variables which included: (a) single sex schools (SSSCHOOL), where coeducational schools = 0 and single sex schools = 1; and (b) a variable which estimates the effects of girls schools only (GSSCHOOL), where coeducational and single sex boys schools = 0, and single sex girls schools =1. The analyses using these variables are discussed below.

Liking of Science

The influence of student sex on girls' and boys' liking of science is presented in Table 10.5, which shows significant effects of sex on liking of science since the t-ratio is 3.17, and the probability is less than 0.05. The South Australian senior secondary boys liked science more than the girls, since the mean score of boys for liking science is significantly higher than the mean score of girls.

The results for the multi-level analysis of the effects of sex at the student and school level on liking of science are presented in Table 10.6 and shows a significant effect of student sex on liking of science. This effect is highly significant, with a t value of coefficient G_{10} of 3.99. The positive sign of the coefficient for the SSEX slope G_{10} = 0.184 shows that boys like science more than girls, since boys are coded 0 and girls coded 1. However, no differences between school types were observed for liking of science. The sample of girls' schools contained only one government school and one

Catholic school and there were two Catholic boys schools. Thus there was a rather small number of single-sex schools in the 29 schools sampled during this study. This sample of single-sex schools was possibly too small for any sound conclusions to be drawn with regard to the effects of sex of school on students' liking of science.

Table 10.5 The effect of student sex on liking of science

Group	N[a]	t-ratio	p-value	Mean	se[b]	sd[c]	Diff[d] (se)	Effect Size[e]	Effect Size[g] Category
LikeSci[f]	1199	3.17	0.001	2.22	0.051	0.59	0.20 (0.062)	0.34	Small
Female (F)	602			2.12	0.050				
Male (M)	597			2.32	0.051				

a: number; b: jackknife standard error of mean; c: standard deviation; d: difference female mean-male mean; e: effect size obtained by dividing the difference between the two groups by the total standard deviation;
f: students' liking of science; g :for effect size classification see Chapter 5 and Cohen (1969, p. 25).

Table 10.6 Results from the multi-level analysis of the effects of sex on students' liking of science

Final estimation of fixed effects:

Fixed Effects	Coefficient	s e	t-ratio	p-value
INTRCPT 1, B_0				
INTRCPT 2, G_{00}	2.180	0.198	11.03	0.000
SSSCHOOL, G_{01}	-0.121	0.136	-0.891	0.381
GSSCHOOL, G_{02}	-0.098	0.166	-0.598	0.561
SSEX slope, B1				
INTRCPT 2, G_{10}	0.184	0.046	3.99	0.001

Reliability estimates Intercept 1, B_0 = O.233, SSEX, B_1 = 0.086

Final estimation of variance components:

Random Effect	Standard Deviation	Variance Component	df	χ^2	p-value
INTRCPT 1, U_0	0.199	0.039	22	31.45	0.087
SSEX slope, U_1	0.068	0.005	24	27.35	0.288
level-1, r	0.689	0.475			

se = standard error; SSEX = sex of student; SCHSEX = sex of school;
SSSCHOOL = single-sex school; GSSCHOOL = girls' single-sex school;
INTRCPT = intercept; t-ratio = estimated coefficient/standard error.

Choice of Science Subjects

The results for the analysis using WesVarPC of the effect of school sex on girls' and boys' choices of science subjects in further education are shown in Table 10.7. Unlike the analysis for liking of science, the WesVarPC analysis for students' expectations to include science subjects in further studies shows no significant effects, because the t-ratio is only 0.480, and the probability is much greater than 0.05.

The results for the multi-level analysis of the effects of sex at the student and school level on students' expectations to include science subjects in further education are shown in Table 10.8.

Table 10.8 shows that with regard to students' expectations to include science subjects in further studies, no effects are significant at either the micro- or the macro-level.

Table 10.7 The effect of student sex on expectations to include science subjects in further education

Group	N[a]	t-ratio	p-value	Mean	se[b]	sd[c]	Diff[d] (se)	Effect Size[e]	Effect Size Category[g]
Sci Subs[f]	1199	0.480	0.315	0.42	0.023	0.59	0.02 (0.039)	0.03	trivial
Male (M)	602			0.41	0.030				
Female (F)	597			0.43	0.030				

a: number; b: jack knife standard error of mean; c: standard deviation; d: difference female mean-male mean; e: effect size obtained by dividing the difference between the two groups by the total standard deviation; f: students' expectations to include science subjects in further education; g: for effect size classification see Chapter 5 and Cohen (1969, p. 25).

Table 10.8 Results from the multi-level analysis of the effects of sex on students' expectations to include science subjects in further education

Final estimation of fixed effects:

Fixed Effects	Coefficient	s e	t-ratio	p-value
INTRCPT 1, B0				
INTRCPT 2, G00	0.234	0.106	2.202	0.037
SSSCHOOL, G01	0.049	0.072	0.688	0.497
GSSCHOOL, G02	0.113	0.088	1.283	0.211
SSEX slope, B1				
INTRCPT 2, G10	0.004	0.034	0.103	0.919

Reliability estimates Intercept 1, B0 = O.240, SSEX, B1 = 0.211

Final estimation of variance components:

Random Effect	Standard Deviation	Variance Component	df	χ^2	p-value
INTRCPT 1, Uo	0.139	0.019	22	22.79	0.414
SSEX slope, U1	0.081	0.007	24	26.11	0.347
level-1, r	0.472	0.222			

se = standard error; SSEX = sex of student; SSSCHOOL = single-sex school; GSSCHOOL = girls' single-sex school; INTRCPT = intercept; t-ratio = estimated coefficient/standard error.

Effects of Sex at the Student and School Level on Expectations of Further Science Study

In this present study there were no statistically significant differences between single-sex and coeducational schools in the strength and coherence of views on STS, the liking of science and choices of science subjects in further education. This is unexpected on the basis of information on the advantages of single sex schools provided by some previous studies.

However, many of these early studies were conducted in British schools, and they related to the 1970s (Byrne and Hazel, 1992b). As a consequence, these previous studies may be out of date in regard to the recent changes in social expectations of females, which have resulted in the increased participation by females both in higher education and in science and technology. It may also not be possible to compare the findings of British and Australian studies in a conclusive way, since different social pressures influence educational achievement, aspirations and expectations in these two countries. Byrne and Hazel (1992b) cited British evidence that significantly more girls in the 1970s in single-sex schools recorded that they liked science than girls in coeducational schools, but that unfortunately there was little corresponding evidence for Australia.

Furthermore, these authors suggested that direct comparisons on the basis of school type were not valid unless the data were controlled and adjusted to allow for:

a) a generally higher intake in the majority of single sex schools which are academically selective; and
b) different social class intakes between types of schools. (Byrne and Hazel, 1992b, p. 3)

In addition to the continuing dialogue on the effects of sex on educational outcomes, during the past 11 years there has been a substantial amount of debate and disagreement between research workers with respect to the effects of single-sex and coeducational secondary schools and classes on students' attitudes and achievements. This debate has involved critical reappraisal and reanalysis by researchers of the findings and conclusions of studies conducted by other researchers. Much of this dissension has centred upon the techniques of statistical analysis used to analyse the multi-level data relating to the relative attitudes, academic pathways, understandings and educational performance of students in single-sex schools or classes as compared with students in coeducational classes. In the present study, however, HLM was used for a valid analysis of this multi-level data. It is unfortunate, therefore, that the sample size of single sex schools did not allow more definite conclusions on gender effects to be drawn. This information would certainly assist the provision of science education for all in Australia.

Appropriate educational policies, commitment by educational leaders within schools and education departments, and the provision of effective teaching resources, are necessary in order for the curriculum shift towards STS to continue to assist the trend towards gender equity in access to science and technology in Australian secondary schools. As Parker, Rennie and Harding have concluded:

> Policy and the provision of resources must operate jointly to ensure that school curricula and supporting materials are informed by the now considerable knowledge about how girls and boys learn science, and how they choose to continue with science. Fundamental in this regard is compulsory study of gender-inclusive, broadly based, multidisciplinary science curriculum, together with substantial, nonsexist career education and structured opportunities for personal and social development, particularly in relation to the interaction between science and society. (Parker, Rennie and Harding, 1995, p. 208)

There is need for continued support to provide females with opportunities to participate in science education from the STS-perspective in South Australia. As has been shown in this present study, females hold different views towards STS issues, which are both stronger and more coherent than those of males.

Summary

Substantial evidence in support of the provision of increased educational and employment opportunities for girls in science and technology have been provided by studies in relation to the differences in educational achievement of girls and boys in science. The suggestion advanced by Gray (1981) that differences between males and females in visuo-spatial abilities produced differences in science achievement has received little support in recent debates. Girls' under-achievement in science has been argued to be more a result of social factors rather than biological factors (Manthorpe, 1982; Keeves and Kotte, 1992). These findings, as well as the increased value given to females' abilities and perspectives have resulted in increased opportunities for females to contribute to the development and use of science and technology in Australia. Over the past 20 years in Australia there has been a transformation of community expectations of the social roles of females. In addition, major programs and initiatives have proved to be effective in engendering greater equality of opportunity in the availability of science education for all.

Studies of female participation in science and technology have shown that females are particularly interested in the social relevance of science and technology. The inclusion of social relevance in science curricula has helped to address gender imbalance in achievement in science by catering for both the learning styles of girls and girls' ways of thinking about moral and social issues. Since in the late 1990s, science and technology have had an increasing impact upon societies and natural environments, this way of thinking is needed in professions involving science and technology.

The effects of single-sex schools compared with co-educational schools with regard to the strength and coherence of students' views on STS have also been examined in this chapter. No statistically significant differences were found between the strength and coherence of the views on STS between schools of different sex (ie. co-educational, single-sex girls, and single-sex boys). Furthermore, the sex of the school did not have a significant effect upon students' liking of science. There were also no statistically significant differences between single-sex and coeducational schools in terms of students' expectations to include science subjects in further education. Hence the results of this study did not support the hypotheses that girls were more successful if they were educated in a single-sex school as suggested by Harding (1981).

In this study, however, because of the small number of single sex, boys and girls schools, it was not possible to find significant effects for the sex of school on any of the outcome variables. On the basis of the review of the literature it is possible to argue that if there were more single-sex girls' schools in this study, some statistically significant effects of school sex on students' liking of science and expectations to include science subjects in further education might have been found.

At the school level, the strength and coherence of girls' views on STS was consistently of a higher level than that of the boys. Significant effects for sex of student were found on all three scales using analysis of variance with SPSS and WesVarPC to give the jackknife standard errors. The examination, which used HLM, showed significant gender effects of the sex of student for both the *Science* and *Scientists* scales, but not for the *Society* scales. It was also shown that girls liked science more than boys.

The findings of this present study suggest that greater participation by females in science and technology might result from a curriculum shift towards the inclusion of STS objectives in senior secondary science curricula. The results also support previous findings that the STS response profile was gender-dependent (Zoller, 1990), since a relationship was found between gender of students and the strength and coherence of students' views on STS. Significant gender-based correlations were seen for a number of STS issues. In particular, significant differences between the STS views of girls and boys were found in regard to STS issues that related to the human element of science. The inclusion of discussion of the issues of STS in secondary science curricula should, therefore, provide extra motivation for all students, but especially for girls, by giving them an opportunity to see the relevance of their studies. Hence, the inclusion of STS in senior secondary science curricula in South Australia is expected to continue to assist to remove the limitations associated with the differences between the sexes in the study of science.

In the technologically dependent Australian society, there are a large number of issues resulting from the interactions between science, technology and society. Thus it is of considerable interest to know the views of young Australians on the issues of STS. Do these views differ between different groups of young Australians? Moreover, do the groups of young people in Australia differ from the STS views of young people in other countries? The views of groups of young people on a selection of STS issues forms the basis of the discussion in the next chapter.

11

Young People's Views on the Issues of STS

Young people in modern societies are growing up in a world that is affected increasingly by science and technology. The views, beliefs and attitudes of young people on issues resulting from the use of science and technology in society are a momentous topic for consideration. It will be recalled from Chapter 7 that throughout history, benefits as well as negative effects have ensued from the use of science and technology in society. Pollution problems are apparent in most countries in the world, and in order to ensure the quality of the lives of future citizens it is important that present citizens insist that these problems are fixed. If this environmental responsibility is not achieved, there appears to be scant purpose in using science and technology with the aim of promoting economic growth and making life better.

The appropriateness of decision-making on the use of science and technology is likely to influence greatly the quality of the lives of future citizens. Decisions on the problems investigated by scientists need to be sound. The views of young Australians, the future citizens and decision-makers, on these problems, as well as on the issues of scientists' motivations, methods and political involvement are important items for investigation and consideration in order to ensure a positive future for the nation.

The views, attitudes and beliefs of Year 12 students were measured in this South Australian study. At the same time as the South Australian study was being undertaken, an Australian study (Eckersley, 1996a, b) of young people's views of the future, was conducted with the support of the Australian Science, Technology and Engineering Council (ASTEC), as part of its larger *Future Needs 2000 Foresight Program* (Eckersley, 1996b). The findings of this ASTEC study, which involved 950 young Australians aged between 15 and 24 years, are relevant to this South Australian study, since science and technology were common features of young people's visions of the future. The ASTEC study of young people found that:

> While they acknowledge the potential of S &T as a powerful tool in achieving a preferred future, young people do not believe in technical fixes to our problems and are very concerned about some future impacts of scientific and technological advances. (Eckersley, 1996b, p. 7)

Consideration of the nature of the views, beliefs and attitudes in relation to STS of the young Australians in both the present study and the ASTEC study is important to assist in the design of curricula which would prepare students adequately for an informed role in STS debates and decision-making. After this first comparison of the STS views of two groups of Australian students, the views of the Canadian students in the original VOSTS study (Aikenhead, Fleming and Ryan, 1987) are compared with the views of the South Australian students in the present study.

Comparisons with the ASTEC Study

The ASTEC study assessed young people's views in regard to issues resulting from the use of science and technology in society. Some of these views were similar to the young people's views gauged in this South Australian study. A discussion of some of the findings of the ASTEC study thus provides a framework for a worthwhile comparison with the South Australian students' views that are considered below. The discussion focuses upon the influence of science and technology on society (*Science*).

The Benefits and Negative Effects of the Use of Science and Technology

The ASTEC study found that just over 38 per cent of young Australians in the survey believed that the benefits of science and technology were greater than the disadvantages, while nine per cent believed that science and technology had more disadvantages than benefits (Eckersley, 1996a, p.13). The South Australian study did not assess young people's views on whether the benefits of science and technology were greater than the disadvantages, although the instrument used in the South Australian study included Item 17 on the trade-offs between the benefits and negative effects of science and technology.

Item 17, shown in Panel 11.1, sought views about the trade-offs or compromises between the positive and negative effects of science and technology. The South Australian study permitted a greater diversity of views to be displayed on this issue than those that were obtained in the ASTEC study. The reasons given by the respondents for the firm belief in the predominance of the benefits of science and technology, by way of example, were that the negative effects could be either minimised (Response G, 10%) or eliminated (Response H, 10%) through careful planning and testing. Five per cent of the South Australian students believed that some new developments provided benefits without producing negative effects (Response F, 5%).

Those South Australian students who believed that there were always trade-offs between the benefits and negative effects of science and technology (Responses A + B + C + D = 57 %), were able to qualify this belief further. The alternative responses which were included in Item 17 enabled students to show that they did not simply hold an overriding belief in the negative effects of the use of science and technology in society. This is clearly an advantage that the instrument used in the South Australian study had over the three response categories (agree, disagree, don't know) or four response categories (better than now, same as now, worse than now, and don't know) that were used in the ASTEC study.

Science, Technology and the Causes of Environmental and Social Problems

An increased effort by members of the public through changing lifestyles, in addition to the use of science and technology, was viewed by a substantial number of young people in both studies as necessary to solve pollution problems. Panel 11.2 shows the responses to Item 24 on the use of science and technology to fix pollution problems.

Panel 11.1 Item 17

17. We always have to make trade-offs (compromises) between the positive and negative effects of science and technology.

Your position, basically: (Please read from A to K, and then choose ONE only from this page.)

There are always trade-offs between benefits and negative effects:

A. because every new development has at least one negative result. If we didn't put up with the negative results, we would not progress to enjoy the benefits. (16%)
B. because scientists cannot predict the long-term effects of new developments, in spite of careful planning and testing. We have to take the chance. (14%)
C. because things that benefit some people will be negative for someone else. This depends on a person's viewpoint. (17%)
D. because you can't get positive results without first trying a new idea and then working out its negative effects. (10%)
E. but the trade-offs make no sense (For example: Why invent labour saving devices which cause more unemployment? or Why defend a country with nuclear weapons which threaten life on earth?). (8%)

There are NOT always trade-offs between benefits and negative effects:

F. because some new developments benefit us without producing negative effects. (5%)
G. because negative effects can be minimised through careful planning and testing. (10%)
H. because negative effects can be eliminated through careful planning and testing. Otherwise, a new development is not used. (10%)
I. I don't understand. (5%)
J. I don't know enough about this subject to make a choice. (5%)
K. None of these choices fits my basic viewpoint.

a: percentages of respondents for each view shown in brackets

Panel 11.2 Item 24

24. We have to be concerned about pollution problems that are unsolvable today. Science and technology cannot necessarily fix these problems in the future.

Your position, basically: (Please read from A to I, and then choose ONE only from this page.)

Science and technology can NOT fix such problems:

A. because science and technology are the reason that we have pollution problems in the first place. More science and technology will bring more pollution problems. (8%)
B. because pollution problems are so bad today they are already beyond the ability of science and technology to fix them. (7%)
C. because pollution problems are becoming so bad that they may soon be beyond the ability of science and technology to fix them. (13%)
D. No one can predict what science and technology will be able to fix in the future. (24%)
E. Science and technology alone cannot fix pollution problems. It is everyone's responsibility. The public must insist that fixing these problems is a top priority. (34%)
F. Science and technology can fix such problems, because the success at solving problems in the past means science and technology will be successful in the future at fixing pollution problems. (4%)
G. I don't understand. (3%)
H. I don't know enough about this subject to make a choice. (3%)
I. None of these choices fits my basic viewpoint. (4%)

a: percentages of respondents for each view shown in brackets

Students' responses to this Item indicated that 34 per cent of the South Australian students surveyed believed that science and technology alone could not fix pollution problems (Response E), since it was also considered necessary for the public to insist that fixing these problems was a top priority. Item a in Table 11.1 summarises the three responses to a similar item in the ASTEC study in which 52 per cent of respondents thought it was necessary to change lifestyles as well as use science, in order to find ways to solve environmental problems.

Table 11.1 Results of the ASTEC study (in per cent)

a. The opinions of young Australians on the specific effects of S&T and lifestyles on environmental problems in the future		Agree	Disagree	Don't know
Science and technology will find ways of solving environmental problems without the need to change our lifestyle		45	52	3
b. The expectations of young Australians on the specific effects of S & T on social problems in the future	Better than now	Same as now	Worse than now	Don't know
The gap between rich and poor Australians' family life.	12	34	50	4
c. The opinions of young Australians on the specific effects of S&T and the social problems of unemployment		Agree	Disagree	Don't know
Computers and robots are taking over jobs, increasing unemployment.		58	40	3
d. The opinions of young Australians on the specific effects of S&T on the quality of life in the future		Agree	Disagree	Don't know
Science and technology offer the best hope for meeting the challenges ahead of us		69	28	3
e. The opinions of young Australians on the specific effects of S &T on alienation of people.		Agree	Disagree	Don't know
Science and technology are alienating and isolating people from each other and from nature.		53	43	4
f. The expectations of young Australians on the specific effects of S & T on the future economy	Better than now	Same as now	Worse than now	Don't know
Australia's national economy	31	28	36	5

(modified from Eckersley, 1996b)

The additional information provided by the South Australian study was related to the students' views on both the magnitude of the pollution problem and the reasons for the problem. The view that science and technology would not solve this problem because the problem was already too bad to be fixed by science and technology, was held by seven per cent of students (Response B), and 13 per cent (Response C) of students believed that the problems may soon be so bad that they may be beyond the ability of science and technology to fix them. Eight per cent of students in their response to Item 24 (Response A) viewed science and technology as the cause of pollution.

The belief that no one can predict what science and technology will be able to fix in the future, Response D, was chosen by 24 per cent of students.

Response F, that science and technology can fix pollution problems, was chosen by only four per cent of South Australian students, a substantially smaller proportion than those who selected the less guarded Response D. It will be recalled from Chapter 6 that although science and technology could provide considerable assistance to the alleviation of pollution problems, there was no universal technological remedy for pollution problems (Ehrlich and Ehrlich, 1970). Thus, the students' responses to Item 24 show that a substantial number of South Australian students had quite coherent views on the issues of fixing pollution problems in the future.

Science, Technology and the Quality of Life in the Future

Item b in Table 11.1 shows that 50 per cent of the young people in the ASTEC study believed that in the future, the gap between rich and poor Australians' family life would be worse than now. The ASTEC study also found as shown in Item c in Table 11.1 that 58 per cent of the respondents believed that computers and robots were taking over jobs and increasing unemployment.

Although some young Australians had concerns that science and technology might cause unemployment and a possible increase in the gap between the rich and poor, Item d in Table 11.1 shows that the conviction that science and technology offered the best hope for humans to meet the challenges of the future was ascribed to by 69 per cent of the respondents in the ASTEC study. As shown in Item 22 in Panel 11.3, the consideration that science and technology might lead to an increase in the standard of living without causing negative effects was highlighted by 37 per cent (Responses A + B + C) of the young South Australians in the present study. However, one response in Item 22 (Response E) which identified aspects that were negative effects of the use of science and technology to make life easier, healthier and more efficient, was chosen by 40 per cent of the South Australian students. These students believed that the quality of life might not improve in line with the increase in the standard of living. In a similar way, it was found in the ASTEC study, as shown in Item e in Table 11.1 that 53 per cent of the respondents believed that science and technology were alienating and isolating people from each other and from nature.

Panel 11.3 Item 22

22. More technology will improve the standard of living for Australians.

Your position, basically: (Please read from A to I, and then choose ONE only from this page).

A. Yes, because technology has always improved the standard of living, and there is no reason for it to stop now. (14%)

B. Yes, because the more we know, the better we can solve our problems and take care of ourselves. (13%)

C. Yes, because technology creates jobs and prosperity. Technology helps life become easier, more efficient and more fun. (10%)

D. Yes, but only for those who can afford to use it. More technology will cut jobs and cause more people to fall below the poverty line. (8%)

E. Yes and no. More technology would make life easier, healthier and more efficient. BUT more technology would cause more pollution, unemployment and other problems. The standard of living may improve, but the quality of life may not. (40 %)

F. No. We are irresponsible with the technology we have now; for example, our production of weapons and using up our natural resources. (8%)

G. I don't understand. (2%)

H. I don't know enough about this subject to make a choice. (1%)

I. None of these choices fits my basic viewpoint. (4%)

a: percentages of respondents for each view shown in brackets

Item 22, shown in Panel 11.3, examined further issues resulting from the effects of science and technology upon the quality of life in society, since it was concerned with whether or not technology would improve the standard of living for Australians. The belief that science and technology made life easier, healthier and more efficient, but at the same time caused pollution, unemployment and other problems, was held by 40 per cent (Response E) of the young South Australians. A further eight per cent (Response F) viewed science and technology as a means of improving the standard of living only for those who could afford to use it. Students in this eight per cent believed that more technology would cut jobs and cause a greater number of people to fall below the poverty line.

Science, Technology and Economic Growth

The views of young people in South Australia on the contribution that science and technology might make to the improvement of life for humans by promoting economic growth are shown in Item 2 in Panel 11.4. Sixty-five per cent (Responses A + B + C) of the young South Australians displayed optimism for the future in their belief that science and technology would lead to an increase in Australia's wealth. The view that this depended upon the types of science and technology invested in, and that there might be ways besides science and technology to create wealth for Australia, was agreed to by 22 per cent of students (Response D). The view, which contrasted substantially, that science and technology, cost money, and thus decreased Australia's wealth, was offered by only three per cent of students (Response E).

Item f in Table 11.1 shows that the expectations of the young people in the ASTEC study of the effect of science and technology on the economy in the future were less positive than the views of young people in the South Australian study. Thirty-six per cent of the ASTEC respondents believed that science and technology would affect the economy to make it worse than now, and 31 per cent believed that science and technology would make Australia's economy better in the future than it is now.

This South Australian study found that young people's views on STS issues in Australian society which is increasingly dependent upon and affected by science and technology were, on the whole, stronger and more coherent than the STS views of the young people in the ASTEC study.

Panel 11.4 Item 2

2. The more Australia's science and technology develop, the wealthier Australia will become.

Your position, basically: (Please read from A to H and then choose ONE only from this page.)

Science and technology will increase Australia's wealth:

A. because science and technology bring greater efficiency, productivity and progress. (26%)

B. because more science and technology would make Australia less dependent on other countries. We could produce things for ourselves. (27%)

C. because Australia could sell new ideas and technology to other countries for profit. (12%)

D. It depends on which science and technologies we invest in. Some outcomes are risky. There may be other ways besides science and technology that create wealth for Australia. (22%)

E. Science and technology decrease Australia's wealth because it costs a great deal of money to develop science and technology. (3%)

F. I don't understand. (1%)

G. I don't know enough about this subject to make a choice. (5%)

H. None of these choices fits my basic viewpoint. (3%)

a: percentages of respondents for each view shown in brackets

Comparisons with the VOSTS Study

There are no published reports of Australian studies using the VOSTS instrument to gather young people's views on STS, even though Eckersley's 1996 study used different methods, which included a national opinion poll and scenario-development workshops for gathering young people's STS views in regard to the influence of science and technology on society. Thus, it is of interest to consider how the views of Canadian high school students in the original VOSTS study (Aikenhead, Fleming and Ryan, 1987) compare with the views of South Australian students in this present study. In this section, the STS views of the Canadian students in the VOSTS study and the South Australian students in the present study are compared and contrasted.

It is stated in Chapter 5 that the original VOSTS study (Aikenhead, Fleming and Ryan, 1987) in Canada aimed to develop an instrument to monitor, in an accurate way, the views on science, technology and society issues of a large sample (10,800) of high school students. A random 30 per cent sample of the high school students' conceptualisations of STS issues was analysed, and students' positions were presented. Since these positions were the basis of the alternate responses for each of the VOSTS statements, a comparison of the percentages of Canadian and South Australian students' positions on STS issues is of considerable interest. In this present study, the percentages of South Australian students' positions on the STS issues discussed were calculated from the numbers of students choosing each of the responses to the VOSTS items. The Canadian students' positions on the various STS issues were reported by Aikenhead (1987) and Fleming (1987) after the analysis of data collected from young people in the VOSTS study in the form of paraphrased common arguments. Thus, since it is not possible to make detailed comparisons of all specific statements and responses between these two studies, this discussion can only cover more general comparisons of selected responses. A summary of the Canadian responses, which are comparable with the South Australian students' responses, is given in Table 11.2. Issues, which are focussed upon in this discussion, are those concerned with the characteristics of scientists (*Scientists*) and the influence of society upon science and technology (*Society*).

Decision-making on the Use of Science and Technology in Society

Panel 11.5 shows the South Australian students' views on the role of governments, community agencies and scientists in making decisions on developments in science and technology. The views of the Canadian students are shown in Table 11.2a. Views on who was to be given the authority to make decisions on the type of energy used in the future ranged from a view in which scientists and engineers made the decisions to a view in which the public were the ones to decide.

Panel 11.5 Item 16

16. Scientists and engineers should be the ones to decide what types of energy Australia will use in the future (for example, nuclear, hydro, solar, or coal burning) because scientists and engineers are the people who know the facts best.

Your position, basically: (Please read from A to J, and then choose ONE only from this page.)

Scientists and engineers should decide:

A. because they have the training and facts which give them a better understanding of the issue. (13%)

B. because they have the knowledge and can make better decisions than government bureaucrats or private companies, both of whom have vested interests. (10%)

C. because they have the training and facts which give them a better understanding; BUT the public should be involved—either informed or consulted. (20%)

D. The decision should be made equally; viewpoints of scientists and engineers, other specialists, and the informed public should all be considered in decisions which affect our society. (33%)

E. The government should decide because the issue is basically a political one; BUT scientists and engineers should give advice. (4%)

F. The public should decide because the decision affects everyone; BUT scientists and engineers should give advice. (11%)

G. The public should decide because the public serves as a check on the scientists and engineers. Scientists and engineers have idealistic and narrow views on the issue and thus pay little attention to consequences. (2%)

H. I don't understand. (4%)

I. I don't know enough about this subject to make a choice. (3%)

J. None of these choices fits my basic viewpoint. (0%)

a: percentages of respondents for each view shown in brackets

The technocratic response, which involved the decisions being made by scientists and engineers, was favoured by 46 per cent of the Canadian students (Response i) and 23 per cent of the South Australian students (Responses A + B). The democratic model was preferred by 46 per cent of the South Australian students (Responses D + F + G) and 50 per cent of Canadian students (Response ii).

The democratic view involved the decisions being made after the viewpoints of the informed public were considered. This view of decision-making has been promoted by eminent researchers in education, philosophy and sociology of science, and public policy as the means of achieving a sustainable future for society (Chapters 2, 3, & 7).

Table 11.2 Student responses to statements in the VOSTS (Canadian) study[m]

a. Scientists and engineers should be the ones to decide what types of energy Canada will use in the future because scientists and engineers are the people who know the facts best.	Canadian students (%)
i. Technocratic response	46
ii. Democratic response	50
iii. Other	4
Total	100
b. Community or government agencies should tell scientists what to investigate; otherwise scientists will investigate what is of interest only to them	**Canadian students (%)**
i. All parties should have an equal say. Government agencies and scientists together should decide what needs to be studied, even though scientists are usually informed about society's needs.	14
ii. Other	86
Total	100
c. Politics affects Canadian scientists, because scientists are very much part of society (that is, scientists are not isolated from society)	**Canadian students (%)**
i. Scientists ARE affected by politics	86
ii. Other	14
Total	100

m: modified from Fleming (1987)

Thus, this discussion of previous research studies reinforces the finding that senior secondary high school students in South Australia had strong and coherent views on STS. Moreover, the views of South Australian high school students on this issue were more coherent than the Canadian students' views, since a greater number of Canadian students than South Australian students favoured the view in which scientists and technologists should be the sole decision-makers.

These responses, which suggested that scientists and technologists alone should make decisions on the use of science and technology in society, had low scores (either 1 or 2) in the scale used in the South Australian study after consideration of the literature published by the experts (see Chapter 6).

Decision-making on the Problems Investigated by Scientists

Both the Canadian and South Australian studies sought students' views on the role of community or government in decisions on which problems were to be investigated by scientists in the future. In the South Australian study it was considered that since there was a finite amount of funding and expertise, these decisions determined the direction of scientific and technological advance (see Chapter 6). Panel 11.6 gives the views of the South Australian students on this issue. Table 11.2b shows the views of the Canadian students on this issue. It was found that a far greater proportion of South Australian students (Response C = 33%) than Canadian students (Response i = 14%) believed that decisions on the research problems investigated by scientists should be shared by government agencies and scientists. This response received the highest scale value (4) in the South Australian study, so again this finding indicates that the STS views of South Australian students were more coherent towards STS perspectives than the views of the Canadian students in the 1987 study.

Panel 11.6 Item 9

9. Community or government agencies should tell scientists what to investigate; otherwise scientists will investigate what is of interest only to them.

Your position, basically: (Please read from A to J, and then choose ONE only from this page.)

Community or government agencies should tell scientists what to investigate:

A. so that the scientists' work can help improve society. (11%)

B. only for important public problems; otherwise scientists should decide what to investigate. (10%)

C. All parties should have an equal say. Government agencies and scientists together should decide what needs to be done. (33%)

D. Scientists should mostly decide what to investigate, because they know what needs to be studied. Community or government agencies usually know little about science; their advice however, might sometimes be helpful. (13%)

E. Scientists should mostly decide because they know best: which areas are ready for a breakthrough, which areas have the experts available, which areas have the available technology, and which areas have the greatest chance of helping society. (11%)

F. Scientists should decide what to investigate, because they alone know what needs to be studied. Governments often put their own interests ahead of society's needs. (6%)

G. Scientists should be free to decide what to investigate, because they must be interested in their work in order to be creative and successful. (7%)

H. I don't understand. (6%)

I. I don't know enough about this subject to make a choice. (3%)

J. None of these choices fits my basic viewpoint. (0%)

a: percentages of respondents for each view shown in brackets

The Effect of Politics on Scientists

The reasons given by both groups of students for the close interrelationship between politics and science were quite varied. Panel 11.7 shows South Australians students' views on the effect of politics on Australian scientists. Table 11.2d shows the Canadian students' views on the effect of politics on Canadian scientists. Eighty-six per cent of the Canadians (Response i) and 74 per cent of the South Australians (Responses A + B + C + D) involved in the studies considered that scientists were affected by politics.

Panel 11.7 Item 19

19. Politics in Australia affects Australian scientists, because scientists are very much part of Australian society (that is, scientists are not isolated from society).

Your position, basically: (Please read from A to J and then choose ONE only from this page.)

Scientists ARE affected by Australian politics:

A. because funding for science comes mainly from governments which control the way the money is spent. Scientists sometimes have to lobby for funds. (29%)

B. because governments not only give money for research, they set policy regarding new developments. This policy directly affects the type of projects scientists will work on. (21%)

C. because scientists are a part of society and are affected like everyone else. (17%)

D. because scientists try to help society and thus they are closely tied to society. (7%)

Scientists are NOT affected by Australian politics:

E. because the nature of a scientist's world prevents scientist from becoming involved politically. (3%)

F. because scientists are isolated from society; their work receives no public media attention unless they make a spectacular discovery. (4%)

G. because Australia is a free country, and so scientists can work quite freely. (4%)

H. I don't understand. (6%)

I. I don't know enough about this subject to make a choice. (9%)

J. None of these choices fits my basic viewpoint. (0%)

a: percentages of respondents for each view shown in brackets

There is a close interrelationship between politics and science, since the practitioners of science, the scientists, are affected significantly by the political climate, as discussed in Chapter 7. Thus, on this issue, the views of both South Australian and Canadian students were strong and coherent with respect to STS views.

Scientists' Motivation for Generating Scientific Knowledge

Panel 11.8 presents the proportions of South Australian students responding to Item 27 on the main reason behind scientists' personal motivation for doing science.

Table 11.3a shows the proportions of Canadian students' responses to this issue. This is an important topic for discussion, since individual scientists' motivation for working hard has a substantial effect on the progression of scientific understanding. Earning recognition was viewed as the principal motivation of scientists by slightly fewer South Australian students (Response A = 8%) than Canadian students (i = 11%).

Panel 11.8 Item 27

27. Most Australian scientists are motivated to work hard. The MAIN reason behind their *personal* motivation for doing science is:

Your position, basically: (Please read from A to K, and then choose ONE only from this page.)

A. earning recognition, otherwise their work would not be accepted. (8%)
B. earning money, because society pressures scientists to strive after financial rewards. (7%)
C. acquiring a bit of fame, fortune and power, because scientists are like anyone else. (10%)
D. satisfying their curiosity about the natural world, because they like to learn more all the time and solve mysteries of the physical and biological universe. (14%)
E. solving curious problems for personal knowledge, AND discovering new ideas or inventing new things that benefit society (for example, medical cures, answers to pollution, etc.). Together these represent the main personal motivation of most scientists. (23%)
F. unselfishly inventing and discovering new things for technology. (3%)
G. discovering new ideas or inventing new things that benefit society (for example, medical cures, answers to pollution, etc.). (6%)
H. It's not possible to generalise because the main personal motivation of scientists varies from scientist to scientist. (24%)
I. I don't understand. (1%)
J. I don't know enough about this subject to make a choice.(4%)
K. None of these choices fits my basic viewpoint. (0%)

a: percentages of respondents for each view shown in brackets

The view that financial gain is the main motivation of most scientists was advocated by only seven per cent of South Australian students (Response B) and 14 per cent of Canadian students (Response ii). The desire to satisfy their interest or curiosity about the natural world was viewed as scientists' main motivation by 43 per cent of Canadian students (Response iii). However, this view of scientists' main motivation was held by only 14 per cent of South Australian students (Response D). The cogent response that generalisations on this issue were not possible, since as human beings, scientists' main personal motivations varied from person to person, was stressed by 24 per cent of the South Australian students (Response H) and only by nine per cent of Canadian students (Response iv).

Consideration of the responses of the Canadian students and South Australian students on the major motivation of scientists suggests that the South Australian students' views on this STS issue were more coherent towards the STS position than those of the Canadian students. Aikenhead concluded that since the statement relating to scientists, as human beings, having a variety of individual motivations, was closest to the motivations of real scientists "a large majority of students seem out of touch with authentic science on the issue of motivation" (Aikenhead, 1987, p. 481).

The Method used by the Best Scientists

Coherent views on the method used by the best scientists is a component of meaningful views on STS. Panel 11.9 shows the South Australian students' views on the methods used by the best scientists. The comparison of the Canadian high school students' views shown in Table 11.3, with those of the South Australian high school students reveals that a much greater percentage of the Canadian students (Response i = 50%) than the South Australian students (18%) (Responses A + B) believed that the best scientists were those who followed the steps of the scientific method. A smaller percentage of Canadian students (Response ii = 14%) than South Australian students (Responses D + E = 31%) held the view that the scientific method did not ensure results, so the best scientists would use other methods as well. This group of students believed that progress in science resulted when scientists were free to use any method that might get favourable results. The middle position, that the best scientists used the scientific method coupled with originality and creativity, was given the highest scale value in the present study. This coherent response was favoured by a substantially smaller percentage (14%) (Response iii) of the Canadian students compared with the South Australian students (Response C = 36%).

Panel 11.9 Item 11

11. The best scientists are those who follow the steps of the scientific method.

Your position, basically: (Please read from A to H, and then choose ONE only from this page.)

A. The scientific method ensures valid, clear, logical and accurate results. Thus, most scientists will follow the steps of the scientific method. (12%)

B. The scientific method should work well for most scientists; based on what we learned in school. (6%)

C. The scientific method is useful in many instances. but it does not ensure results. Thus, the best scientists will also use originality and creativity. (36%)

D. The best scientists are those who use any method that might get favourable results (including the method of imagination and creativity). (12%)

E. Many scientific discoveries were made by accident, and not by sticking to the scientific method. (19%)

F. I don't understand. (3%)

G. I don't know enough about this subject to make a choice. (8%)

H. None of these choices fits my basic viewpoint. (4%)

a: percentages of respondents for each view shown in brackets

The above comparisons of the views of the young South Australians in the present study with the Canadian students in the VOSTS study in 1987 indicate that young South Australians have relatively high-level or coherent views on a selection of STS issues. The coherence of respondents' views was indicated, in the South Australian study, by comparison with the views of seven experts, who each provided an independent scaling of the 27 items used in the instrument. The young South Australians' coherent views on STS might well have been due to the move, in recent years in South Australia, to present a meaningful view of the nature of both the social relevance of science and the human element of science in present South Australian upper secondary science courses. This suggestion is supported by the findings of the researchers in the VOSTS study that some of the Canadian students did not understand the scientific method and blamed this upon not having studied "the stories of scientists" (Aikenhead, 1987, p. 470).

Table 11.3 Student responses to statements in the VOSTS (Canadian) study[m]

a. Most scientists are motivated to work hard. The MAIN reason behind their *personal* motivation for doing science is:	Canadian students (%)
i. Earning recognition	11
ii. Earning money	14
iii. Satisfying their curiosity about the natural world	43
iv. It's not possible to generalise because the main personal motivation of scientists varies from scientist to scientist.	9
v. Other options	32
Total	100
b. The method used by the best scientists	
i. The best scientists were those who followed the steps of the scientific m ethod.	50
ii. the scientific method did not ensure results, so the best scientists would use other methods as well.	14
iii. the best scientists used the scientific method coupled with originality and creativity	14
iv. Other options	22
Total	100

m: modified from Aikenhead (1987)

Young South Australians' more coherent views on a selection of STS issues in comparison with the views of the young Canadians, might also be due to the increased emphasis on STS issues by the Australian media in recent years. In Chapter 3, it was argued that in Australia, the media had a strong influence on the development of young people's views on the nature of science and the issues of STS (NBEET, 1994).

Summary

In this chapter, the coherence of the young South Australians' views on a selection of STS issues was compared with that of the views of two other groups of young people. The STS views of a higher percentage of young South Australians were found to be coherent, or of a high score, than the views of young people in either another Australian study, the ASTEC study, or the Canadian VOSTS study.

A large number of the young South Australians believed, by way of example, that science and technology would lead to an increase in Australia's wealth, although they also held the opinion that when science and technology were used in Australia to improve the standard of living, the quality of life might not improve. More than half of the young people in South Australia held the view that there were always trade-offs between the benefits and negative effects of science and technology. A greater percentage of young people in the South Australian study than in either of the other studies believed that since science and technology alone could not fix pollution problems, the public should insist that sufficient resources were devoted to the solution of these problems.

In the light of the discussion of the level and coherence of the STS views of young South Australians, it is important to note that the democratic model of decision-making on the use of science and technology in society was favoured by 46 per cent of the South Australian students. A high level and coherent understanding of the methods used by scientists was held by 31 per cent of the South Australian senior secondary students. The majority of young South Australians were of the sound opinion that scientists were individuals with a range of motivations, and their imagination, creativity, and originality would feature prominently in the methods they used to obtain favourable results.

The success of a curriculum shift in providing for positive learning outcomes for students does, however, depend upon teachers' views and understandings in relation to this aspect of the curriculum, since teachers can only teach what they understand well (Lederman, 1986). At this stage in South Australia, with science curricula which include STS objectives at both the junior and senior secondary levels, an examination of teachers' STS views is necessary in order to provide further support for the findings outlined in this chapter. This examination of teachers' views of STS is undertaken in the next chapter.

12

Teachers' Views

Changes in curriculum emphases require changes in teachers' beliefs, teaching styles and resources, as well as increased time demands and workloads. Hence, a curriculum change is unlikely to be implemented successfully if teachers do not consider that there is a need for such a change. Furthermore, the indispensable condition for instruction indicates that teachers are only able to teach effectively what they understand well (Lederman, 1986, p. 97). Therefore, the successful implementation of a curriculum change also depends upon the adequacy of teachers' understanding of aspects of the curriculum addressed by the change. In order to facilitate the successful introduction of educational change, in the early stages of the implementation of the change it is important to examine teachers' views, understandings and concerns in relation to the changes (Fullan, 1992).

The Need to Consider Teachers' Views on Curriculum Changes

Teachers are often blamed for their students' poor understanding in relation to certain aspects of the curriculum (Ebenezer and Zoller, 1993). This exacerbates teachers' feelings of insecurity in relation to their understanding of a new aspect of the curriculum. Rather than blaming teachers, some fairly pragmatic researchers have suggested that more effective planning and research prior to the introduction of a curriculum change, as well as consideration of students' views and attitudes both before and after the implementation of the changed curriculum, would aid the design and planning of strategies to overcome this problem. In a Canadian study, which investigated students' views and attitudes in response to a curriculum shift towards STS, Ebenezer and Zoller (1993) argued, for example, that no change in students' views and attitudes towards school science in British Columbia had resulted as a consequence of the introduction of the STS approach to science education. On the basis of the review of the literature on the student-level effects of the introduction of courses which include STS objectives, (see Chapters 1 and 3), a significant change in a positive direction in students' views and attitudes towards school science in British Columbia should have been expected after the shift towards the STS approach to science teaching. In the search for an explanation of this lack of change in students' views the authors looked towards the science teachers. Therefore the authors argued that more consideration was needed with regard to the role of the teachers and their teaching styles if an educational change were to incorporate a coherent, STS direction (Ebenezer and Zoller, 1993). Once a greater emphasis is placed on teachers' roles in achieving an educational change in an STS direction, in-service courses and professional development programs may be provided to assist teachers to increase their understanding to the level required to teach this aspect of the curriculum with confidence.

Successful implementation of innovations in curriculum content or emphases requires the support of appropriate teacher in-service programs (Fullan, 1992). Thomas (1987) supported the need for professional development of teachers in relation to STS when he wrote that it was often difficult for teachers, who had been trained to teach pure science, to deal with consideration of the issues of STS in their science classes, because this aspect of science teaching questioned the absolute certainty of scientific knowledge. Furthermore, innovative teaching techniques such as role plays, brainstorming and community-oriented projects in small groups, often constitute the most effective vehicles for facilitating students' understanding of STS concepts, and some science teachers might not be confident in the use of these techniques. Thus, in this investigation of the curriculum shift towards the inclusion of STS objectives in Australian secondary science courses, it is important to gather and consider teachers' views, beliefs, understandings and concerns in regard to this curriculum shift. The results of such an investigation could be expected to assist the development of effective professional development programs for teachers.

The collection and consideration of teachers' views, concerns, and understandings in relation to the recent curriculum changes towards the inclusion of STS objectives in secondary science courses in South Australian schools was undertaken in both a qualitative and quantitative manner in this study. The results of the structured interviews, which constituted the method of gathering qualitative data on teachers' views, are discussed in this chapter. Before presenting these results, however, the findings of previous studies on teachers' views are discussed in order to provide a framework for the examination of the findings of this present study.

Teachers' Views on the Curriculum Shift Towards STS

Previous studies of teachers' views and the development of teachers' professional competence in relation to curriculum shifts have highlighted the benefit of studies such as the present one for the development of effective teacher in-service education. A longitudinal study of the views of teachers in the United Kingdom (Carre and Carter, 1993) found that teachers registered a considerable increase over two years in their perceived competence to assist students to achieve understanding of the statements of attainment in the National Science Curriculum. The conclusion reached was that this 1989-1991 examination of British teachers' perceived self estimate of their professional knowledge and skills in teaching had implications for both teacher education and curriculum development and implementation. Another study of the implications for science education of teachers' views about the nature of science (Lakin and Wellington, 1994) also concluded that the results of the study might be used for teacher education by providing pointers to the provision of in-service education in this area.

Rubba (1989) advanced his belief that it was necessary for science teachers to hold a valid understanding of issues ensuing from the interaction between science, technology and society if the teachers were to help their students develop adequate understandings. This concern necessitates consideration of how the adequacy of teachers' and students' views is determined. Aikenhead (1988) considered the information about STS views that was gained or lost by using traditional instruments and concluded that although semistructured interviews were time consuming to carry out, they offered the most accurate and most readily comprehensible data.

The structured interview component of this present investigation aimed to gather South Australian secondary science teachers' views on the shift towards the inclusion of STS objectives in secondary science curricula. Questions, which formed the basis of these interviews, were designed to investigate teachers' perceptions of the adequacy of their professional knowledge and the efficacy of their teaching strategies, as well as of the resources and in-service support provided for the effective introduction of this curriculum change. The questions also sought information on teachers' understanding of the nature and importance of the interrelationship between science, technology and society. Teachers' understanding of the nature of science formed the focus of one question, since this understanding provided the foundation for all of their science teaching.

When teachers are confronted with a new curriculum, which requires them to teach the nature of science and the nature of STS issues, the framework presented may not be supported by all teachers. As a consequence, when confronted with a curriculum shift requiring them to teach a new aspect of science, teachers may feel alienated from the given ideas or concepts (Lakin and Wellington, 1994). Thus, further questions sought the teachers' concerns with regard to teaching about the nature of STS issues.

The Group Interviews

Group interviews were conducted during this study with 101 science teachers from 23 metropolitan and non-metropolitan co-educational and single-sex secondary schools and colleges from the government, independent and Catholic education systems that agreed to take part in these interviews. Since the purpose of the overall study was to investigate and evaluate the curriculum change associated with the inclusion of studies of STS in secondary science courses in South Australia, the views of teachers were considered to be important in influencing the success of such a curriculum change. The interviews were, therefore, conducted with the aim of obtaining more detailed information on how the teachers viewed the curriculum change towards the inclusion of STS issues in secondary science courses in South Australia. These objectives were features of the SACE syllabi at the Senior Secondary level, (Senior Secondary Assessment Board of South Australia [SSABSA], 1991a,b, c, d; 1992b,c, d, e) and the National Statements and Profiles at all levels (Curriculum Corporation, 1994 a, b). For the purposes of this study, the interviews provided supplementary information to that gathered by the instrument, although the instrument was administered to teachers as well as students. During the interviews the teachers were asked six questions. The interviews were recorded on cassette tapes. After each interview the following aspects of the interviews were also documented:

(a) the general ambience, or atmosphere in the schools;

(b) any special considerations for the teachers in the particular school; and

(c) anything of relevance for the study which was said, but not recorded.

The first step in the analysis of the interviews consisted of listening to all of the tapes. The tapes were summarised after all of the interviews had been reviewed. The next step was to classify the material relevant to each particular question. Subsequently, the teachers' responses to the six questions were clearly recorded in tabular form on a large chart to enable the numbers of specific responses to be accurately counted and recorded. The views of the teachers concerning the particular aspects of STS, which formed the basis of the six questions, are discussed in the following section.

1. What is Your Understanding of STS? Why Teach STS?

A common view or understanding of STS education, which was presented by teachers in 19 of the 23 interview groups, was that the inclusion of studies in STS in secondary science courses was a way of considering the social relevance of the scientific concepts discussed in science classes.

The need to make science education more socially relevant was considered by teachers from 16 of the 23 groups to be sufficient justification for the inclusion of STS in secondary science education. A young female teacher from a metropolitan government school stressed, by way of example, that:

> ..STS education is good educational practice, as it is a way of teaching science for life.

A young male teacher from a metropolitan non-government girls school confirmed this view and further suggested that:

> ..STS education is an important way of preparing students for their place in society, as the emphasis in the community is on science and technology.

In response to the second part of this question, 80 per cent of the secondary science teachers involved in the interviews in this study acknowledged that STS education represented a shift in the focus of science courses in order to make the material more relevant and meaningful for students in relation to the real world around them, thereby providing motivation for learning. Teachers in 21 of the interview groups believed that when discussions in science classes began with some aspect of technology with which the students were familiar, it was possible to help students to "make the links", and then to build upon the students' prior understanding. This constructivist approach, which was employed in STS education, was, for instance, advocated by a female teacher from a co-educational government school in the northern suburbs of Adelaide when she asserted that:

> It's good to start with something that's relevant and then build ideas onto this.

The suggestion was made by teachers in five of the groups that as the STS aspect of science was inherently the most interesting part of the course for a large number of students, this motivational aspect, coupled with the provision of links between everyday life and the content of science courses, was sufficient reason for teaching STS. A young female teacher from a non-government school in Adelaide, for instance, reinforced this view in her answer that:

> When the curriculum is related back to what students know, and can see around them, in their homes, in the community, in the streets, etc, they all relate to what you're teaching in this context, and respond well. This is much better than just giving them the cold, hard facts, where there's no correlation.

In addition, a middle-aged male teacher from a metropolitan government co-educational school agreed that:

> The STS or technology and society part of science is inherently more interesting to a lot of people, so in the sense of making the science more interesting, it is worth it for that alone.

A group of teachers from a co-educational government school in the outer northern suburbs of Adelaide emphasised that STS was definitely a big "turn on" for students, since they enjoyed discussing something they had gained knowledge of through the media and on television. After the students had discussed the implications of the interrelationship between science, technology and society it was, according to the teachers, possible to provide the students with more knowledge on a particular topic.

The views of teachers from three schools of diverse composition were that most contemporary students did not learn for the sake of learning, but had to be provided constantly with motivation and suitable contextualising activities. This need for motivation and questioning of the content of science courses was fairly new, in the opinions of the teachers. The teachers believed that 20 years ago, secondary science students were motivated in a different way, and would simply learn the material that was presented to them. This is probably a consequence of increased retention rates, through which students of all levels of ability now remain at school.

There were great variations in teachers' expectations with regard to the students' ability as future citizens to influence the direction of Australian science and technology. However, this was predominantly due to the teachers' cynicism, as they did not foresee a situation where the Government would allow science policy to be influenced significantly by public debate. The importance of teaching STS so that citizens would be enabled to participate in informed debates on the directions of science and technology was highlighted by 18 teachers in three of the groups in the study. One of these teachers, a female teacher, who was employed by a non-government co-educational school in the northwestern suburbs of Adelaide, stressed vehemently that:

> It's important to get students to believe that technology doesn't just lead us human beings, but we have to empower ourselves to say that there's a part of a technology such as military warfare that we do not like to see heading in a certain direction, and we have the power to stop it. It's not satisfactory to think that we have no say in what scientists develop.

Reinforcement of this opinion was also provided by a female teacher from a government girls school when she said that the inclusion of STS in the science curriculum:

> ..is of great value, as this more open-ended approach to problem solving will enable students to take an active part in future decisions on social problems relating to science and technology.

A female teacher from a non-government co-educational school also argued that:

> Discussions of STS issues help students to see that they have a social conscience and the ability to stop some developments in science and technology.

However, this view was not shared by four other groups who suggested that although STS empowered citizens to influence the direction of science policy, this could be accomplished in a more passive manner through their ability to make informed choices at the polling booth.

A middle-aged male teacher from a prominent non-government boys' school supplied an enlightened concluding statement that:

> ..unless the students developed an understanding of issues such as environmental pollution, they would not be much good as voters of the future. It is important for citizens through science education to become educated voters who would act to produce appropriate changes in legislation in future years.

A male teacher from a government co-educational school also stressed that:

> ..kids, as potential voters can influence decision-making in relation to science and technology.

Great support for STS was demonstrated by a male teacher from a prominent non-government boys' school in Adelaide when he discussed the importance of STS in achieving the educational goal of teaching the "whole person" in order for students as adults to take their place as vital participants in society. This view was accepted by a progressive group of science teachers from a non-government school in the southern suburbs of Adelaide. They suggested that students, as potential voters, should have a balanced view on issues such as mining. As science and technology shape the modern world, in their views, it was important to have in-depth knowledge and understanding of the issues before decisions were made, rather than just to believe and accept the "media hype."

Teachers who had entered teaching from another professional background, or who had additional experience in a non-scientific discipline framed enlightened and interesting responses to this question. A background of making Rolls Royce airplanes and working on the Concorde when he lived in England led one male teacher to be appalled at how little social relevance was being taught when he entered the teaching profession in Australia. In this teacher's opinion the Concorde, by way of illustration, was one of the finest planes ever made, and yet it was criticised by the public, since they did not want that sort of plane, with its high noise levels. He said that although industry was blamed for what went wrong, education did not encourage future citizens to consider ways of doing things differently. The science classes conducted by this teacher were, therefore, loaded heavily with discussions of STS issues, although, in his opinion, these areas were not covered sufficiently in the rest of the school.

A male drama and science teacher, who had qualifications in both areas, gave a reply that was enlightened in a similar way. As a result of his experience discussing issues in drama lessons, he considered that the discussions of STS issues in his science classes were particularly effective. These discussions of issues began, for instance, with a class discussion of a television show about Marconi, and then progressed to consideration of the microchip on the back of the master card. This was then tied in with the theoretical work on the structure of the atom and electronic transfer.

The responses to this question included direct reference to technology in some cases, since these teachers believed that the technological developments in contemporary societies were of such great significance to students' lives that they should form the basis of science courses. This focus upon technology was observed by the teachers in all of the boys' schools in the study, as well as in the schools that had been boys schools, but had changed to become co-educational schools. These teachers used a large number of hands-on resources including computers, CD roms, electronic mail, interfacing and advanced microscopes with their classes in order to "demonstrate the impact of technology upon society". These applications were also used in co-educational private schools, and large metropolitan government schools in fairly affluent areas. A male teacher from a metropolitan private school that had changed to become co-educational suggested that there were two aspects to STS education that were important to address:

> ..areas where science or technology is having an impact on curricula in terms of looking at what scientists do and the way they work (that is) environmental impact and what you're doing in terms of hands on technology.

The same teacher stressed, however, that although there was a reason for teaching STS, he liked it to be integrated well, so that the remaining objectives could also be addressed. As a consequence of the emphasis upon technology in this school, one of the male students who was sampled in this survey had such ready access to advanced technology that he requested that a copy of the results of the survey should be forwarded to him through his e-mail number.

The view that it was unnecessary to extend what he believed was STS to a deeper coverage, since it was easy for even the least able students to understand, was emphasised by an older science teacher from a non-government metropolitan boys school. Furthermore, another male teacher from a non-government metropolitan co-educational school considered the imposition of STS in the South Australian secondary science curricula to be an intrusion, as he did not wish to spend time debating social issues in his lessons. This teacher suggested, "that should be done in a subject called politics."

There were marked differences in the teachers' attitudes to this curriculum change. A chemistry and biology teacher from a government girls' school in Adelaide cited increased student awareness as the reason for teaching STS. In his opinion, this increased awareness had resulted in "the expectation, by students, that scientists be more humane, and have more responsibility for their decisions." Another teacher from this same school, however, promoted the image of science and technology as providing infallible "solutions" to social problems, and made the rather naive suggestion that the reason for teaching STS was to teach students how to solve social problems. In order to represent science adequately, a teacher from a non-government boys school suggested that he showed students the importance of science in improving the quality of human life, while providing demonstrations of the limitations and undesired consequences of technology, such as environmental problems.

STS education was considered by a female teacher from a co-educational government school in the southern suburbs of Adelaide in terms of its effect upon teachers, since it was a good way of keeping teachers in tune with providing the context for the content of science courses and reading the literature in journals such as science teachers journals. In the opinion of this young female teacher, some teachers would not normally tend to make their courses socially relevant.

Only two groups of teachers from the 23 groups of teachers interviewed in this study could not give a strong reason for the inclusion of STS in South Australian secondary science curricula. In one of these cases, a male biology teacher in his late 30s from a non-metropolitan government school related his view to the time needed to cover all of the content of science courses. He said:

> We've just got so many courses that we never get through. There isn't a strong reason for teaching STS as such. We don't therefore teach it as the foundation of science classes, just incidentally as the opportunity arises.

The other teacher who did not give a reason for teaching STS was from a small private Christian school that did not follow the SACE curricula in all of their secondary science classes. This teacher was more concerned with teaching science from the Christian point of view than with the inclusion of the discussion of STS issues.

The senior science coordinator from a rather progressive area school in the non-metropolitan area suggested that the inclusion of STS in South Australian secondary science curricula was a very positive move, as it provided a new approach to thinking about teaching science in a social context. He likened the influence of the SACE curricula and the National Statement and Profiles to the effect of the introduction of the ASEP units when he said the new courses:

> ..make you think back to ASEP in the seventies, which drew attention to the sorts of topics that you could teach in schools to prepare them for when they leave school. This was a major change in the seventies in terms of philosophy, and how you went about things, so it is comparable to this. I just felt that it gave me a new approach to things, and thinking about issues such as petroleum. Well, we should maybe learn something about this, and do it in a particular way so

> that the kids feel that their lives intertwine with what we're trying to teach them in the classroom.

The vast majority of teachers believed that it was important to include discussions of STS in secondary science classes. Hence, it was considered important to discuss the ways in which South Australian secondary science teachers incorporated STS into their subject teaching.

2. How do you Incorporate STS into your Subject Teaching?

When asked this question, teachers in four of the groups responded immediately by citing the social relevance report that was a component of the assessment of both the Year 12 Chemistry and Biology courses. In order to complete this report, students chose some area of science and technology as their topic, and wrote a report on its relevance for society. These reports were evidence of the definite move to include STS as a compulsory aspect of senior science courses, since STS was included in all Year 12 Chemistry and Year 12 Biology courses. More than half of the teachers stressed that Year 11 Chemistry and Year 11 Biology courses also included STS, since it was necessary for students to achieve the STS objectives in order to complete the course in a satisfactory manner. However, as one male physics teacher from a Catholic co-educational school suggested, it was surprising that there was no social relevance report in physics, since physics, according to this teacher, lent itself well to the discussion of issues such as nuclear power and the health aspect of radiation therapy.

At the Junior Secondary level, STS was included in the science classes of 70 per cent of the teachers involved in this study. A female teacher from an Adelaide boys' school suggested that STS should be compulsory at the junior levels so that students would become accustomed to that kind of teaching. This teacher regularly included a substantial component of STS in her junior secondary science classes, and found that it was meaningful for the students and that she really enjoyed teaching STS.

As well as having incorporated a component of STS into their Junior Secondary Science classes, some teachers had designed and taught specific courses with an STS basis. A teacher from a non-government metropolitan school had, by way of example, designed a Year 10 Geology course to give students a balanced understanding of the issue of mining, and he had used this course with his classes for many years. Another resourceful male teacher from a metropolitan government school claimed:

> My whole philosophy runs around STS and I run courses with kids to do with things outside the school. I have kids working at CSIRO with scientists and using the opportunity to do some real scientific research. I also have a student working with staff at the art gallery. This 'hands on' science shows students how science makes a real impact on society. As the students work with the scientists, all of their knowledge actually ties in with the relevance of this knowledge.

When discussing scientific concepts in their science classes, teachers suggested that they often used STS examples from outside the students' school experience in order to contextualise the work. They included discussion of the movie Jurassic Park and DNA fingerprinting in the O.J. Simpson trial where genetics was discussed. Research and discussion occurred in relation to the different kinds of social influences on scientists, and therefore on the direction of development of scientific knowledge and on ethical considerations in the use of nuclear power, atomic bombs, genetic engineering and reproductive technologies such as *in vitro* fertilisation. A rather interesting STS activity was included in the science lessons of a female teacher from a non-government metropolitan girls school. This activity involved looking at the flavours in ice cream and discovering that "some of the substances used were poisonous and that others were used in rubber cement." Science teachers from a non-government metropolitan boys school took the students on an excursion to Holden's automobile production plant so they could investigate new paint jobs. In this way, it was believed, the students would see the social relevance of the chemical process of corrosion. Another interesting excursion embarked upon by a biology class from a metropolitan government school was a visit to the Dry Creek saltpans. The biology teacher expressed the view that:

> This allowed students to observe an excellent bird life conservation area, while also being provided with an example of industry and technology working to the benefit of society. Technology doesn't necessarily need to be out of step with the environment.

A group of teachers from a non-metropolitan government school said that they did some robotics with their students in order to include STS in their teaching. Another example of the incorporation of STS in science teaching was given by a young male science teacher from a Catholic school who considered that because of the nature of the school, it was important to talk about science in reference to the Church in some of his lessons. He did this by discussing examples from the history of science, such as the early astronomer Galileo, who had great difficulty in having his scientific work accepted, because it was contrary to the religious philosophy of the Catholic Church at that time.

The science team from a non-metropolitan government school reported that they had completely re-written their Junior Science programs so that they were more coherent with the Profiles, and the new courses were considered to be:

> ..more socially relevant and less content-oriented than the past ones. They also have more socially relevant names. If we were doing electricity, we'd call the topic 'Power Station' and we'd try to include as much as possible on the power station and take the students out to look at the power station. We would also get people in to talk about how the station works as well as covering all of content material on electricity.

A teacher from another non-metropolitan government school added that it was extremely important to choose issues that had relevance for the students. As the school in which he worked was in a winemaking area, they had developed a unit on wine making, and discussed the social relevance in relation to the effects of alcohol on society.

In ten of the schools, STS was incorporated into science courses in rather innovative ways as a consequence of the nature of the school or the student population. In one non-Government metropolitan school with a large number of boarders from country areas, for instance, STS issues were discussed regularly in the study of agricultural science and environmental science topics at the Junior and Senior Secondary levels. The issues discussed included disease control, the effect of technologies such as genetic engineering on livestock breeding, pollution produced from automobile exhausts, global warming, and the appropriate balance in the use of capital-intensive technology. One of the male senior science teachers made the following interesting comment on the desirability of educating students regarding the need for balance in the use of technology in society, otherwise:

> If there were a few weeds out there, instead of getting a shovel and doing something about it, kids will be coming up with some 'whiz bang' idea, which costs a fortune, and creates other problems. They're looking for a 'simple fix' for every problem.

It was suggested by teachers in almost half of the interviews that "marrying theory and practice" by discussing the social relevance of science was nothing new, as they had, in their opinions, always done that in their teaching. Examples of strategies that 15 teachers from three interview groups had used in past years to include STS in their classes were given in support of the claim that STS was "nothing new". When discussing filtration in chemistry classes, for example, they had provided the context by discussing filtration plants. The teachers suggested that the inclusion of STS had, however been formalised now that the STS objectives had to be assessed. One senior male science teacher from a non-government metropolitan school complained that:

> I think that we've been doing all right. Our teachers have tried to relate technology, and even the social relevance, to their teaching. I think that we have been doing it all along, but since the particular aspect has been formally assessed it has detracted from the teaching of the science.

A group of teachers from a government metropolitan school agreed that STS had been included in their science classes since they started teaching, but they did not like to be told that they had to assess as well as teach it, since there were always strict time limits on what they were able to cover in their lessons.

An experienced male science teacher from a non-government boys' school concluded that there had not been a sudden change in the importance of teaching technology when he said:

> ..there has, however, not been a sudden turn-around or decision on the importance of teaching technology. In my own teaching career it has always been done, and we've always framed test questions in an everyday context. When teaching about electricity, for example, we've taught students how to use electricity and electrical appliances safely. I don't see what all the fuss is about really.

A middle-aged female teacher from a government girls' school asserted that:

> As a biology teacher, I've always taught that sort of scientific method at Year 11 and Year 12 in detail, and now it's also in the Junior school.

It was significant that even those teachers who had always included STS in their teaching suggested that it was now formalised, as it had become a compulsory component of the course assessment. Of all the teachers who were interviewed, only one teacher from a non-metropolitan school suggested that he only taught STS in an incidental, indirect way when the topics fitted in with the course work. He gave an example of teaching the effects of antibiotics on society in regard to population and death rates.

Since it is necessary to include STS in science courses, an appraisal of the resources which teachers use for teaching STS would be informative.

3. What Resources do you use for Teaching STS?

Aikenhead (1995) reached the significant conclusion that since contextual values influenced scientific activity, teachers needed to use appropriate curriculum materials in STS education to teach reflective and well-considered decision-making. Aikenhead's conclusion concurs with the view maintained throughout this work. It is therefore of considerable concern that in response to this question on the resources teachers used for teaching STS, 90 per cent of the teachers replied initially that there was a lack of appropriate resources and that there were never enough materials. The teachers then continued to outline the texts and materials with which they were familiar. More than half of the teachers in both government and non-government schools suggested that it was difficult to find the time to research STS issues to include in their classes, and that a solution would be provided by increased access to a central resource pack. Three groups of teachers from non-government co-educational metropolitan and non-metropolitan secondary schools highlighted the need for a centralised location for a variety of resources. These teachers considered that increased access to resources would facilitate the inclusion of discussions about specific STS topics in their lessons, thereby helping students to achieve the objectives. The views of another group of teachers from a government co-educational secondary school reinforced the views of the first group, as they said that:

> In terms of resources we're just taking up the challenge now. But you always have a situation where the developments are just happening, and in biology, for example, there aren't textbooks that specifically cover these developments. This means that you have to do a lot of reading and a lot of other research on your own, and then put the material in a form that students can read and understand. The developments in CD roms and computers will open up this area.

The teachers from non-metropolitan schools considered that they had particular problems in regard to access to STS resources, although their views on possible solutions were similar to the views of the teachers in metropolitan schools, as discussed above. The science team from a fairly isolated non-metropolitan government school, by way of example, suggested that it was particularly difficult when they were just presented with a topic and then had to work out a socially relevant program for it. They needed resources because of the lack of time available, and suggested that they would benefit greatly from a central folder of resources and worksheets to function as a starting point for the development of programs. They concluded, however, that this was not possible in country areas such as theirs, as there were no appropriate networks, and they were a long way from more adequately resourced areas. It was encouraging that these teachers were sufficiently optimistic to add that they overcame this problem partially by making their own resources and sharing these resources amongst themselves.

The first resource discussed by most teachers was the textbook. In chemistry, the textbooks used in a number of government schools due to the emphasis in the books on social relevance were *Chem1 and 11* (Heinemann). At Stage 2 they used the book *Chemistry 2002*, as it included material that was relevant for the discussion of STS issues. For Junior Secondary science courses, the textbooks were *Science in Context*, which focussed upon STS material, and recent editions of *Science Alive* and *Science-New Approach*, which also included discussions on the social relevance of science. The teachers suggested that the choice of appropriate junior science books was crucial, as a solid grounding in STS in the Junior Science courses, would prepare students for the STS emphasis of the Stage 1 courses.

A male science teacher from a government metropolitan school recommended the SATIS units from Britain, as he liked the approach, which was employed in these units, of using the scientific method to make sense of a social issue. An STS-based unit *Forensic Science* was recommended by teachers from three schools, since it covered practical issues such as DNA fingerprinting. One teacher from a non-metropolitan government school suggested that many of the available resources were too difficult to include in the Junior Science course. This would make it difficult to achieve the important goal, as discussed previously, of preparing students for their Stage 1 studies. Many teachers also suggested that they used newspaper articles on current STS issues to supplement the material in the textbooks, but few used journal articles, as they usually had an inappropriate reading level, and there was insufficient time to access this resource. Time was certainly regarded as a limiting factor for such a curriculum change, since more than half of the teachers from a variety of schools believed that one of the major difficulties involved in the inclusion of STS was finding the time that was necessary to research appropriate STS issues.

As well as the issue that insufficient time was available for accessing or developing resources, the issue of the funding of STS resources was also focused upon during the teacher interview at the science faculty meeting of a large metropolitan government secondary school. These teachers asserted that the problem was due to the high cost of appropriate textbooks. Biology texts used in this school, for example, were $60 each. These teachers argued that:

> ..many schools have spent enormous amounts of money as new syllabuses have been developed, and schools have not been given an extra budget for this.

Three-quarters of the teachers stated that the funding of other STS resources was also extremely difficult, as many of the resources that would be beneficial in this area, such as videos and computing technology including CD roms were expensive. The teachers also stressed the need for continual updating of resources in this area. A group of teachers from a non-government co-educational school stated their views that:

"As far as videos go there are always financial problems. How can you justify a video for a report that one kid is doing on neutrification of the Patawalonga that will cost $75, and next year nobody will use it? Another aspect of the use of resources is that what was relevant yesterday or even today, may not be relevant tomorrow. Therefore it wouldn't be worth buying a lot of these expensive resources."

The suitability of the resources was discussed by a senior science teacher from a metropolitan government school. He made the important point that one of the major problems with STS was the books and resources, as the books were not integrated, but tended to have the last couple of chapters devoted to technology, or STS. This was a concern for teachers, as when the teachers started to cover an area with their classes, according to the SACE framework, the STS aspects had to be integrated within the overall teaching. This teacher stressed that:

> The resources tend to constrain, rather than to open up opportunities, because they are limited to a society chapter, or a technology chapter.

The other teachers from this group then added their opinions that in the last couple of years books with a greater integration had started to appear, and these had the potential to enable discussion of STS issues in a particular context. Unfortunately, in the opinions of the teachers, such books were still not prevalent.

Another problem with a number of the resources in this area, in the opinion of the science teachers from a co-educational non-government school in Adelaide was that they presented students with a biased view of the issues, as they were written by "Greenies" or sponsored by mining companies and other bodies that had a vested interest in the issues. The teachers asserted that these resources portrayed the issues inadequately, since they only gave one side of the argument, and one possible solution to the problem. In effect, these resources mis-represented the nature of an issue, as there were always two sides to a question. In order to overcome this problem, and to enable the material developed to be appropriate for use with secondary school students, the teachers in a non-government metropolitan girls school emphasised the need for resources to be developed by those actively involved in the work, as only they had the relevant background.

Although it is true that teachers should be involved in the development of STS resources, a group of teachers in a co-educational non-government metropolitan school considered that it was important to note that teachers varied in their ability to use STS materials effectively with students. The members of this group argued that some teachers had found the resources difficult to use for STS education, because:

> ..it's taking them away from their traditional ways of teaching by focusing exclusively upon the basic content.

A reflective teacher from a non-government metropolitan boys school extended this idea to highlight the importance of the teachers' attitudes and knowledge for the effective use of resources in teaching STS when she presented her view that:

> In this area the teacher is the resource, as I've seen in a number of schools in which I've taught, and how it is taught is critical. If you are enthusiastic about something it usually is successful, irrespective of what resources are used.

The teachers involved in these interviews considered that there would be many ways in which resources could be used in the near future to open up the world for science students through studies in STS. Many of these would, according to teachers, use computers and computer applications, such as CD rom encyclopedias, and newspapers in the electronic mail with access to Associated Press and other sources. This would make it possible for students to see what was happening around the world and to observe the decisions that were made. A well-informed male teacher from a non-government metropolitan school highlighted the future potential for the use of resources in STS when he said that:

> A lot of schools in the States are doing e-mail projects where they pick out a social issue and write back and forth to communicate about that issue in their local area. It's easy for others to see what's happening here just by getting on line. In fact it's happening in Australia already, so I often access news groups and discussion groups.

4. Do the Students Respond well to STS Material? Do Girls Respond Particularly well to STS Material?

In every interview, the teachers viewed their students' response to STS as positive, although some teachers had reservations that prohibited them from making an unequivocal reply. The female science coordinator from a government metropolitan school, for instance, added that the students' response depended upon the issue that was being considered. She asserted that:

> If you're talking about biological functions, for girls, the immediacy is important to them, so they take that on in a serious way. However, if you talk about social issues that are of less immediate relevance to them, then they're not interested, eg. a more 'muscular domain', such as the mining industry. Also, the perspective that you put on it and the way in which you allow it to develop, determines the impact.

Another teacher from this school suggested that the questioning process also determined the response, as girls liked to discuss the issues in groups before they framed their responses, whereas boys would prefer to answer quite quickly. Other teachers cited increased work output and more questions being asked by all students when STS issues were being discussed, as proof of the students' positive response to the STS emphasis. A group of teachers from a co-educational metropolitan government school said that students responded especially well if they were taken out of the classroom and into the community, where they could see STS at work. The science coordinator from a metropolitan school of similar structure said that he kept the STS material as practically oriented as possible as then students participated readily and there was no division on the basis of gender.

A teacher from a non-government metropolitan school argued that the teachers at his school overcame this problem by choosing examples that were not only appropriate for boys. If these teachers were talking about parabolic motion, they would not only use football as an example, but would also choose a girls sport. These teachers considered that students responded well to STS, since it was:

> ..student-centred rather than teacher-centred, and an element of choice is provided, since students are able to select what interests them in assessment tasks such as essays and assignments in the junior school, and the social relevance reports in the senior school.

One of the science teachers from a metropolitan non-government boys school stressed that students did not respond well to his attempt to show students the social relevance of their work on kidneys in relation to kidney malfunction in those Adelaide children who had recently suffered from haemolytic uraemic syndrome after eating infected smallgoods. He attributed this problem to the students' lack of awareness of what goes on outside of the school environment. It is interesting that a female teacher from a government metropolitan girls school suggested that she had also experienced some problems when discussing STS with some of the Year 9 students, as:

> Those kids are still working out where they are in relation to themselves and others, rather than thinking about social consequences. They don't seem to have the ability to put themselves in the place of others and understand the consequences.

Teachers' views on the response of junior science students to STS therefore displayed some disagreement, but teachers in 21 of the interview groups held the view that junior science students, as well as senior science students responded well to STS education. This response was obtained from teachers in government and non-government schools that were co-educational, as well as from girls' schools and boys' schools. The female junior science teacher from a prominent non-government metropolitan boys school, for instance, believed that the boys in her classes responded very well to STS. It is significant that this teacher is the one who previously suggested that she was very confident in this area, and "loved doing that".

Despite the views of teachers in 18 of the groups in this survey that all students responded well to STS education, teachers also had reservations in regard to the diligence of the boys and girls in relation to the STS content included in the science curricula. Most teachers also said that there was no great difference in the response of girls and boys to STS content, although a teacher from a non-metropolitan government school advanced the view which corresponded to the views of many other teachers that:

> ..girls seem to approach it a little more diligently than boys do.

A number of reasons were suggested to account for this difference in the academic commitment and the results that were observed for boys and girls in many schools. These reasons ranged from the poorer writing skills of boys to the fact that girls were more mature academically than boys, who were still "keen to promote their self-image at this age."

The poorer writing skills of boys was given by teachers in three of the interview groups as the reason for the different response of boys and girls to STS. These teachers concluded:

> Girls' approaches to STS seem to be more diligent on the whole, and writing skills come into this. Boys often have poor reading and writing skills.
>
> Girls' slightly better response to STS is due to the fact that STS is assessed through writing essays.

> STS is assessed in extended-response-type questions in which girls do better than boys.

A teacher from a non-government boys school said that he had used an exercise where the students discussed nuclear energy in a general science class, but he had found that the students' background knowledge was not sufficient to make it a valuable exercise, and that the boys were "rather sheepish about getting into it, so it dropped by the wayside."

The predominate view of the teachers who were interviewed in this study was that students responded very well to STS material. A group of teachers from a co-educational non-metropolitan school suggested that their senior classes were comprised mainly of girls and in the physics class of eight girls and two boys, the only people who passed were two girls. Girls were achieving very well in science in this school, and although the teachers did not decry the reorientation of girls towards science, they felt that they "needed to encourage the boys more."

5. A Strand of the Statements and Profiles for Australian Schools is "Working Scientifically". What is Science, and how do Scientists Work?

A substantial number of teachers responded according to the classical model of the scientific method, comprising observation, hypothesis, and testing, since this classical methodology of science was presented to these teachers in their undergraduate courses.

In one interview, the teachers simply explained, in order to answer this question, that working scientifically was not really a strand for social relevance, but an area for practising the scientific method. They added that Levels 6, 7 and 8 addressed social relevance, but that this was rarely accomplished in Years 8 to 10, and the students then progressed to their separate subjects for the Senior Secondary years. A teacher from a country school suggested, however, that the working scientifically strand, and consideration of the nature of science "was not a separate topic, but just fitted in basically with everything you did in science classes, including practical and theory work." This teacher, therefore, provided opportunities for her junior science students to consider the nature of science and the way in which scientists worked.

Although teachers in one of the interview groups discussed the dynamic, evolutionary and socially relevant nature of science with their junior secondary science students, this was recognised as not the case for all secondary science students. The vast majority of physics and chemistry teachers only gave the social relevance report as an example of the inclusion of STS issues in their senior secondary science classes. However, the biology teachers in three of the interview groups included discussion of STS issues in their senior secondary science classes. A male teacher from a metropolitan government school explained that science teachers generally presented science as a fairly fixed body of knowledge, but it depended on the background of the teacher. If teachers had sufficient knowledge of the history of the development of a particular aspect of science, they were able to talk about it more authoritatively, and engage in debates. Some young teachers were, nevertheless, quite well informed about the philosophy of science, and suggested that science progressed by inductivism. One particularly vocal young teacher discussed Heisenberg's uncertainty principle, Einstein and the Big Bang theory in relation to religious philosophy. Only two teachers the interview groups named a philosopher of science in their answer to this question, although they were not asked specifically to do so.

There were also some interesting variations in the teachers' views of the nature of science and of the nature of scientific method. A male teacher from a non-government boys school displayed views that diverged from the general body of thought about the methods of science when he recounted his idea that:

> .. science sometimes worked by haphazard groping in the dark in order to get the answers rather than by such a structured process.

The teacher therefore said to a student who was struggling to get results during a practical session:

> Come on, don't be so bound by 'working scientifically', but go by your hunches for a while.

This teacher responded to the second part of the question that:

> ..(the question) has the connotation of what scientists were like as people. They are not necessarily just dull people who go about life thinking about things in a straight and narrow pathway, as they have other interests in life. You cannot, therefore, just give one general, absolute way in which all scientists work.

Similarly, this view that many great scientific discoveries were made by methods other than the traditional scientific method was held by another teacher who concluded that perhaps its major purpose was for verification, so that people could not fudge results. He concluded that the push for objectivity in science became a "religious scientism" where, science was "put on a pedestal." In this teacher's opinion, this attitude led to unfair criticism of meditation and forms of alternative medicine, as the underlying ideas cannot be tested scientifically. This notion was shared by a female teacher from a non-government metropolitan school, who suggested that students whose sick relatives had been cured by the non-traditional methods lost their faith in science, with its foundation in the objective collection of data in order to prove or disprove hypotheses.

Some teachers even included consideration, in their responses, of objectivity and subjectivity, although this was not an issue in most of the teachers' views on the nature of science. Science was objective, in the opinion of a science coordinator from a government metropolitan school in the sense that evidence was criticised by other scientists who all had the same framework by which to judge the work, so "the scientists in effect, put themselves up for scrutiny." When scientists had their work published they were really working to avoid criticism by having it thoroughly documented, and showing that their conclusions followed from their results.

The fact that science was still taught as being objective concerned a male science teacher from a non-government co-educational school, since he did not wish students to have a naive belief that science was always right and that there was a quick "technological fix" for every problem. He tried to address this in his classes to some extent by showing the historical development of ideas such as the nature of the atom. The evolution of different ideas and different models of the atom allowed students to develop a concept of scientific models or theories which were tested with the observations at the time, but were changed or replaced when they failed to fit further observations. A female teacher in a group from a government co-educational school strongly agreed with this view, and included similar discussions in her science classes. Another male teacher from a non-government co-educational school also believed that students should not have overwhelming faith in the power of technology to solve social problems.

A male biology teacher from a non-metropolitan government school was unsure of the meaning of objectivity and subjectivity in relation to science, and defined the scientific method as keeping an open mind, asking questions and testing and probing.

The students at this school were encouraged to use the scientific method right from the beginning in their major research project so that they didn't "botch it." An absolute belief in the objectivity of science was also shown by a female chemistry teacher from a non-government metropolitan school when she defined science as "objective problem solving". One male teacher even doubted that it was necessary to introduce the philosophy of science into secondary classes. When asked about the nature of science he said "That's a philosophical point, and I know that as teachers we grapple with that, but I'm not sure that it's necessary to introduce it into our classes."

The above discussion of teachers' views of the nature of science and the work of scientists, which, as discussed in previous chapters, formed the basis of STS courses, led logically into a discussion of the issues in STS courses that these teachers considered important.

6. What do you see as the Main Issues in STS Courses?

A great deal of similarity was observed in the STS issues that groups of teachers considered to be important. The need for providing in-service courses for teachers in relation to STS education was considered to be a significant issue by teachers in 17 of the interview groups who were interviewed during this study. Both experienced and fairly new teachers believed that adequate in-service programs were not provided in this area. Teachers in 12 of the interview groups considered that in-service courses should focus upon STS issues with which they were not familiar, and one teacher suggested that:

> ..with all of the time filling out profiles, the actual knowledge was lost, and there was very little discussion of STS in my undergraduate course. The most useful information was provided by a conference on genetic disease that I attended two years ago. The profiles meetings that I have been to didn't give any training in this area.

A teacher from a non-government metropolitan boys school also believed that the workshops on Statements and Profiles that he had attended were not particularly useful, although they "broke the ice", as they got teachers together talking about the Statements and Profiles. He concluded:

> But did it boost or increase our knowledge or understanding? No. It seemed to me that we were just going through this for the sake of going through it and being together.

The experienced teachers remembered that there was greater access to in-service courses in the "old days".

The need for more in-depth training of teachers in both the issues of STS and appropriate teaching methods, as a component of their undergraduate courses before they entered the teaching force was also highlighted by teachers from nine of the interview groups. A number of the teachers who were still in their first or second year of teaching had discussed a lot of STS issues in their undergraduate courses, and they found that discussion very useful for their teaching. However, even these teachers stressed that there was a need for constant updating of their knowledge, as things in this area changed all the time. One experienced teacher, nevertheless, remembered covering STS in her undergraduate course. For one of her assignments, it was necessary to visit some industries, which involved technology, and to observe the social impact of these industries.

An emphasis upon the importance of covering the content of science courses in an effort to enable students to achieve high matriculation scores, and, it was suggested, to prepare students for their tertiary studies, was considered to be a major issue by teachers from non-government schools and the larger government schools in metropolitan and non-metropolitan areas. Teachers from eight schools discussed their concern that there was simply not enough time to cover everything that they would like to teach, especially at the upper secondary level.

At one large government school in the metropolitan area the teachers suggested that although there were many sound reasons for including STS in the curriculum, as they had stated in their answer to Question 1, quite often this had resulted in unfortunate cuts in the syllabus material. It was just not possible to fit everything in. In order to emphasise further his concern about the syllabus cuts, one of the teachers from the group recounted the following incident:

> My son is doing science in university, including acid-base theory that has been cut out of the Year 12 syllabus entirely, but is still in the university course. Luckily I was at home when he was having trouble understanding this, as I taught it to him and his friends.

Other teachers who supported this suggestion added that it was very important to cover all of the concepts of the course, and that STS was simply an emphasis in some of the material that was taught in their classes. The older teachers in these schools, in particular, displayed a limited willingness to allocate time in science classes to discuss the nature of science or the influence of "the human face of science" on the development of scientific knowledge, and were predominantly interested in "covering the concepts". A middle-aged male teacher from a government co-educational school reinforced this view in his assertion that:

> Some teachers may look at STS as an external imposition as the first step is to cover the content, and then to build on this.

Teachers from 12 of the groups cited lack of time to search out information so that they were able to address the STS objectives of the secondary science courses. These teachers believed that in order to include STS in their classes consistently they required a regular source of newspaper articles as well as access to appropriate journal articles and videos. This was not as crucial in their own particular field with their matriculation classes, as they believed that they remained relatively up to date with developments in their area of specialisation. They believed that the junior science classes drew upon knowledge from a variety of scientific areas, so it was more difficult to give analogies and stories for the social relevance of science. This was particularly the case for teachers who had completed their training many years ago. The issue of financing of resources and the need for increased access to resources also weighed heavily upon the minds of many teachers.

During the interviews, teachers often drew attention to the fact that time allocation to particular topics in secondary science courses was assessment-driven. These teachers considered this a major issue, as they had to allocate time to teach STS, which formed part of the compulsory student assessment, so they were unable to cover all of the content they had included in science classes in previous years. This also necessitated a change in the forms of teaching and assessment that a number of these teachers had used successfully for many years. One such group of teachers in a government metropolitan secondary school complained that the assessment of the STS component of their courses, the social relevance report took a lot of students' time, and was not, in their opinions, particularly effective. These teachers concluded that:

> Instead of teaching in a context, the STS component becomes an absolute dominance for a short period of time.

This group of teachers would have preferred to use discussions of STS issues to provide relevance throughout their teaching, and to assess it in the final paper. They continued, however, that its inclusion in the Matriculation Chemistry paper in 1994 was not effective, as there was a great deal of reading in the paper as well as a lot of extended response questions. In the opinions of these teachers, some good chemistry students were unable to complete the paper, even with an extra half hour, as their standard of literacy was too low. Their main objection to the STS question was, therefore, that it was an extended-response question that these students could not answer, and could hardly read.

A young male teacher from a non-government girls' school also discussed the 1995 examinations in South Australia, since he believed that the Biology examination contained a question on what was, according to him, a wonderful topic, the *Human Genome Project* and its implications for human disease. However the teacher said that he was:

> ..really interested in how the students did in this exam, as teachers had provided students with very general instruction on the Human Genome Program in regard to definition, risk and benefits, and not all teachers could answer this question.

Assessment of STS was difficult, according to a teacher from a non-metropolitan government school, since it could quite easily become subjective. He further suggested that it was not assessed in the junior school to as great an extent as in the senior school, although it was easier to bring it into discussions at this level, particularly in the area of biology. The trend in assessment in tests and examinations was, in this teacher's opinion to:

> ..draw more on what happens in life and industry, rather than having straight-out recall questions. This sorts out the kids quickly in interpreting the question, and what it's really asking them to do.

The reasonably high standard of literacy required for satisfactory achievement in STS education, as discussed previously in relation to the lack of achievement by some students in the external chemistry examination in 1994, was considered an issue by teachers in three of the interview groups. This was mainly due to the fact that an adequate response to the STS questions required a considerable amount of writing and a fairly well developed level of English comprehension. One teacher suggested that he did not have time to teach scientific writing to his students, and this was part of the job of the English teachers.

It is interesting that there were some obvious contradictions in teachers' views of the issues in relation to the STS emphasis of the new science curricula. The science teaching team from a metropolitan non-government school contended that what was done in science classes was still driven by the curriculum, and this had resulted in more time being given to STS, since the objectives were assessed.

However, a group from a non-metropolitan government school stressed vehemently that:

> ..we have just re-written our programs so that they are more coherent with the profiles, and the new courses are not as content-oriented as the past ones, but are more socially-relevant.

A stark contrast was contained in the statement from a group of teachers from a non-government girls' school that:

> Certain teachers are bored with teaching the normal mundane science, so they're going into the social relevance. Maybe the kids are also bored with the basic content, but it's a matter of time. You can't teach everything.

Discussion

Consideration of teachers' responses to these interview questions appears to indicate that some Australian teachers' understanding of the nature and philosophy of science, and the ways in which scientists work (see answers to Question 5 above) conforms with the traditional empiricist-inductivist model of the scientific method. In this method, observation and experiment provide for the derivation of theories by induction (Chalmers, 1982) (see Chapter 2). The understandings of these teachers might have been constructed from the traditional presentation of the nature and methods of science in their undergraduate studies. A large majority of the teachers in these interviews believed that it was important to emphasise the social relevance of science, since both male and female students responded well to the inclusion of STS in secondary science courses. These teachers gave examples of STS issues that might be discussed in their classes. Moreover, many teachers were concerned about appropriate resources to use when teaching STS and both teaching and assessment methodologies concerned some teachers.

The finding of some teachers' poor understanding of the nature of science in the present study is disturbing, but is not inconsistent with the findings of studies on the views of British science teachers (Ray, 1991; Lakin and Wellington, 1994) and of North American science teachers (Duschl and Wright, 1989; Gallagher, 1991; King, 1991; Rubba and Harkness, 1993). These researchers have also highlighted teachers' insufficient understanding of the nature of science as well as the philosophy and history of science. The science teachers' insecurity about their lack of deep understanding of these issues, as shown in Lakin and Wellington's British study, must be considered to be quite serious, since the scientific method formed a starting point for all components of the curriculum taught by these teachers. This British study indicated that teachers had engaged in little reflection on the nature of science in the period preceding the study (Lakin and Wellington, 1994, p. 186). Thus in a way which is similar to the understandings of some Australian teachers, indicated by the interviews in this study, by pointing out teachers' needs and concerns, the 1994 British study found gaps in the knowledge and awareness of the science teachers involved in that study.

Like the British study, the results of a 1993 study in the United States (Rubba and Harkness, 1993) also showed that large percentages of preservice and in-service teachers held misconceptions about the nature of science as well as about the interactions between science, technology and society. The adequacy of science teachers' conceptions about STS interactions was, therefore, brought into question. The authors reached the significant conclusion that this might have been a factor affecting the degree to which science teachers integrated STS into their classroom discussions of science. Perhaps the way STS was included in South Australian secondary science classes was also affected by the level of some teachers' understanding of these issues.

An earlier study of American teachers' knowledge of, and attitudes towards the history and philosophy of science (King, 1991) aimed to highlight any deficiencies existing in the teachers' backgrounds as well as ways of correcting these deficiencies. Two of the questions included in the questionnaire used in the 1991 study, "What is science? and How is scientific knowledge produced?" are very similar to questions asked of the Australian science teachers, "What is science, and how do scientists work?" Thus consideration of the findings of King's American study is relevant for the discussion of the findings of this Australian study.

King (1991) found that many beginning science teachers in North America stressed the social construction of scientific knowledge and believed that science was neither neutral nor objective. He concluded, however, that after commencing their employment, teachers reverted to thinking according to the classical model of science. This researcher offered the following possible explanation for the change in science teachers' thinking:

> No doubt it is extremely difficult to fly in the face of encyclopedic textbooks, budget and class size constraints, and standardized achievement tests which stress fact acquisition as a measure of scientific knowledge, to create a learning environment which treats scientific knowledge as socially and historically constructed, and constantly changing. (King, 1991, p. 139)

The experienced South Australian teachers involved in this study rarely considered the interrelationships between science, technology and society in their reflections upon the nature of science that were recounted during the interviews. A majority of the responses offered by these teachers were, therefore, couched in terms of the classical model of the empirical scientific method. Most of the teachers' answers were fairly superficial and featured terms such as hypowork, observation and testing, rather than including any consideration of the possible subjectivity in science. Some young teachers answered in terms of the philosophy of science and cited inductivism as the scientific methodology. However a small number of teachers, who were often quite young, or from the area of the biological sciences, acknowledged the human element of science in their answers. In their views, science was more the product of individuals who sometimes worked on hunches and less-structured methods than suggested by the classical model.

The findings of interviews conducted with technology studies teachers in Victoria (De La Rue and Gardner, 1996) in an investigation, which sought to ascertain teachers' attitudes towards environmental and social issues are also significant for this present study. In a way that was similar to this present South Australian study, teachers in each interview were asked to respond to a number of questions which had been prepared previously. In reaction to a question, which was designed to elicit teachers' views on the nature of technology, teachers responded in terms of general definitions of technology. In the South Australian study, teachers also answered in terms of general definitions of science and technology. A similar rejoinder was offered by English teachers during an investigation of teachers' perceptions of technology (Jarvis and Rennie, 1996). The English teachers frequently used the language from the National Curriculum in their statements about technology, but appeared to be confused when they tried to match the view of technology described in the National Curriculum documents with their everyday understanding of the nature of technology.

In a way which was similar to the studies of the views and attitudes of Victorian and English teachers, the fact that many South Australian teachers could give a small number of examples of some of the STS issues that might be included in their lessons bears evidence to the fact that these teachers had read the documents of the Australian National Statements and Profiles and the SACE curriculum statements. However, the answers of some of these teachers to other questions in the interviews indicated that they did not really have a meaningful understanding of the nature or philosophy of science or of the issues of STS. A small number of teachers in three of the interview groups spoke of the objectivity of science and the scientific method, and were not interested in or familiar with the philosophy of science. One group of South Australian teachers said that they did not want consideration of the social relevance to dominate.

The teachers in the Victorian study also said that they did not want consideration of the social and environmental issues to dominate, and expressed similar concerns about time availability as did the teachers in the present South Australian study. The Victorian teachers only wanted to deal with these issues if they were relevant. They felt that curriculum developers had not allocated sufficient time to consider the impact of technology on society in addition to all of the other aspects of the curriculum (De La Rue and Gardner, 1996).

In the present study, two groups of teachers who had previously been secure in teaching the traditional curriculum objectives regarded STS as an intrusion and expressed their annoyance and frustration in terms of time concerns. Teachers who approved of the inclusion of STS objectives in secondary science curricula still expressed concern about finding the time that was necessary both to remain familiar with this aspect of the curriculum and to develop appropriate resources.

Unfortunately many of the teachers in both the British and the South Australian studies viewed the term "philosophy of science", a necessary component of the consideration of STS issues, as a threat. It appears that these teachers were not provided with sufficient opportunities during their undergraduate education to develop understanding of the philosophy of science to enable them to discuss the philosophy and nature of science in their science classes. Furthermore, one group of South Australian teachers concluded vehemently that the requirement for formal assessment of the STS objectives of the course had detracted from the teaching of science. In a way which was similar to this finding in a number of the South Australian teachers, the North American teachers were found not to have been prepared sufficiently in their undergraduate years with historical and philosophical knowledge of science, and thus did not feel confident to teach other than the scientific facts. It was concluded that:

> ..although a clear majority felt that history and philosophy of science should be an important components of their science teaching, they did not have a clue how to teach this way, or even enough knowledge to (in one student's words) 'ask the right questions'. (King, 1991, p. 138)

A further similarity between the South Australian and North American studies was that the teaching of science from the STS perspective made the subject more interesting for students. In two of the interviews in the present study the influence of humans on science and technology was included in the conversation. Two of the 11 teachers in the North American study were concerned, like a majority of the Australian teachers, with covering the content. The two American teachers believed that covering the content was more important than discussing the history and philosophy of science. Since these respondents were just about to begin their teaching career, it is not possible to make a direct comparison with the findings from the interviews with the Australian teachers.

It appears from the interviews that the need to cover the content was of paramount importance to the Australian teachers from all of the three types of schools. This was probably a reflection of the constraints on these teachers due to the assessment system, increased financial restrictions and the teachers' perceived over-riding requirement to prepare students for their university studies in their senior secondary school years. King (1991) explained gaps in teachers' views on the nature of science in terms of budget constraints and an assessment system that emphasised fact acquisition above all else. The constraints that King believed affected the North American teachers' views also affected the Australian teachers. Hence, some of the Australian teachers focussed on covering all of the content, rather than using discussion of the issues of STS to consider the social relevance of science throughout their teaching.

An additional explanation for the resistance shown by some teachers to the curriculum shift towards STS, by complaining that they did not have time to cover all of the content, was suggested by one group of fairly young South Australian teachers. These teachers, who were very confident in their abilities to teach STS, offered their view that the major concern of some teachers in relation to this curriculum change was that they could not teach in their traditional ways, which involved focusing exclusively upon content. Since some of these teachers were the senior staff of some quite influential metropolitan schools, they may have had a significant influence upon the success of this curriculum change. This concern is illustrated by the example discussed above of the middle-aged upper-secondary chemistry teacher in one of the interview groups who strongly expressed his view that it was distressing that the “syllabus cuts” had resulted in a situation where students like his son had not learnt about components of the syllabus such as acid-base theory. A similar reaction by one teacher was observed in the interviews in the earlier North American study, since the teacher believed that:

> ..there’s so much basic material to know that talking about philosophical issues takes away from content. Acids and bases are more important in a chemistry course than history and philosophy of science. (King, 1991, p. 138)

Unfortunately, it is apparent that teachers who consistently stressed this concern that the curriculum shift towards STS would not give them time to cover all of the content, focused their attention in their lessons exclusively on what they perceived to be the effective preparation of senior secondary students for university studies. This is a regrettable and inappropriate emphasis in current times, since as Fensham (1990) has suggested, the decrease in young Australians’ chances of obtaining employment, and the resulting increased retention of students into the upper secondary level has created a need, at this level, for a science education which is stimulating and useful as a preparation for all students’ future lives in society. Thus, the inclusion of STS in secondary science courses is a positive move towards the provision of science for all Australians, but it appears that some teachers are not providing for the achievement of this goal in their science lessons. Discussion of British teachers’ views on the curriculum innovation, which focused upon teaching the nature of science, indicated similar concern in regard to the negative influence that some teachers had on the success of a similar curriculum development. The discussion led to the conclusion that:

> In the past certain innovations in the science curriculum have been teacher-led or at least teacher-driven. Our suspicion is that this innovation will not be- in fact it may even be teacher-impeded. Who will take the lead in curriculum development, which may be running contrary to teachers’ own views of science (and its role as a curriculum subject) and certainly conflicts with popular notions of science and its purposes? (Lakin and Wellington, 1994, p. 188)

The findings of an earlier study (Gallagher, 1991) of the knowledge and beliefs about the philosophy of science of prospective and practising secondary school science teachers also provided for an important comparison with the results of this Australian study. The 1991 study sought to gauge both teachers’ understanding of the nature of science and how this affected their teaching. After considering the views of prospective science teachers enrolled in a course on methods of teaching secondary science, the author concluded that there was a significant emphasis on the transmission of the body of knowledge of science. Gallagher decried this emphasis, since he believed that it would provide young people with an inaccurate and inappropriate image of science. He blamed university courses that emphasised the rapid transmission of scientific knowledge for the development of this view in graduates. It was concluded that:

> Prospective teachers have limited knowledge of, and experience with, the processes by which scientific knowledge is generated. This puts serious

> limitations on their ability to plan and implement lessons that will help the students develop an image of science that goes beyond the familiar body of knowledge. (Gallagher, 1991, p. 131)

The elitist view that the scientific method was "the pinnacle of methodologies" which was " a paradigm for other disciplines to follow", was espoused by a group of British science teachers in the study of teachers' views of the nature of science (Lakin and Wellington, 1994, p. 186). However, in a way, which contrasted with the sense of security gained through the high regard for the scientific method, the science teachers in the British study were insecure about strategies for teaching about the nature of science and STS, as were some of the older South Australian science teachers. Furthermore, it has been suggested that the adequacy of American science teachers' STS understandings influenced the methods they used to integrate consideration of STS issues into their science classes and the quality of the STS instruction (Rubba and Harkness, 1993). It would appear that this is also the case for a reasonable number of South Australian teachers. Thus, few teachers suggested role play, drama, small group work, discussions and excursions as ways of approaching the nature of science in their classes. The reasons given by South Australian teachers for their concern about using innovative teaching strategies and methodologies to incorporate STS into subject teaching included the lack of appropriate resources and experience, as well as education in regard to the effective use of these strategies. Some teachers used role plays with students at both the junior and senior secondary levels, but others suggested that roles were appropriate only for junior secondary science classes, or for single-sex girls' classes.

More innovative Australian teachers suggested strategies for teaching about STS which ranged from excursions to Holden's automobile production plant and bird life conservation areas to projects in robotics, forensic science and viticulture as well as students working with CSIRO scientists and members of staff from the art gallery. A small number of teachers with a highly developed knowledge of computing technology suggested the use of e-mail projects on social issues concerning students from different geographical areas.

Lakin and Wellington (1994) argued that teachers' inability to understand or implement these innovative teaching strategies effectively tied in with science teachers' view that science as a field of study was isolated from the humanities. A similar view was held by a South Australian teacher who said that he believed that social issues should be debated in a subject called politics, rather than allocating time for the consideration of these issues in science lessons. However, a teacher of both science and humanities stressed that although many science teachers believed that teaching strategies used in the two disciplines were quite different, he had experienced success with the combination of traditional strategies from both disciplines in his science lessons. This suggests that it is important to consider teachers' life experiences as well as their formal education when considering their views, understandings and efficacy in relation to the effective inclusion of discussion of the issues of STS in their secondary science lessons.

It is encouraging that teachers from 16 of the 23 interview groups in this Australian study believed that this curriculum shift towards STS presented an opportunity to make science more socially relevant and thereby prepare students for their place in society. One teacher said, for example, that she wanted students to realise that they had the power to influence the development of science and technology. Another believed that it was important for students to have an in-depth understanding of STS issues, rather than just believing the media presentation, which was often highly sensational.

In King's study, 13 students about to graduate from teacher education courses responded to his questionnaire. The more reasoned and articulate responses were given by the three respondents who each referred to science as "an attempt to make sense of the world around us", and each of these students was able to identify at least one well-known philosopher of science such as Popper or Kuhn (King, 1991, p. 137). In the Australian study, valid and well-reasoned responses to the question, what is science, were given by a small number of teachers, but teachers from 17 of the groups could only respond according to the traditional model of the scientific method, or the definition of science given in the documents of the Australian National Statements and Profiles (Curriculum Corporation, 1994a,b). Furthermore, in the structured interviews, only a small number of the younger teachers from three of the interview groups identified a philosopher of science in their answers to questions, although they were not asked specifically to do so.

Lakin and Wellington's (1994) study of British teachers' understanding of the nature of science concluded that there was a pressing need for in-service opportunities and guidance for teachers in exploring and reorganising their own ideas on the nature of science. Similarly, the final important point for discussion or explanation in the South Australian study of teachers' answers to the six questions in the structured interviews relates to teachers' understanding of the nature of science and the issues of STS, and the need for the provision of in-service courses for teachers. Teacher in-service and undergraduate and postgraduate teacher education courses which focus upon increasing teachers' understanding of the issues of STS, would help to meet the gaps in understanding in relation to STS that were found in some of the Australian science teachers involved in the structured interviews.

The focus of these in-service courses should include discussions of:

(a) the nature of the issues stemming from the interrelationships between science, technology and society;

(b) the nature of science, and the nature of scientific knowledge;

(c) the ways in which scientists work; and

(d) well-structured resources to use when discussing STS issues in science classes.

During these courses, flexible and innovative teaching and learning strategies should be employed in order to demonstrate the effectiveness of these teaching and learning strategies. These teaching and learning strategies should include role-plays and facilitated discussions in small groups. These cooperative-learning strategies would also assist networking, which would further assist the achievement of a more effective understanding of these issues by the majority of science teachers.

The Australian teachers' answers to the questions in these interviews highlight the importance of considering whether it is really important to cover all of the traditional scientific content and risk a lack of awareness of the interrelations between science, technology and society. This seems most unlikely. Consideration of teachers' answers to the six structured interview questions, as well as the published literature on similar studies, indicates that it would be better to cover most of the content in a way that provides an understanding of both the interrelations between science, technology and society, and issues confronting the modern world. Discussion of these issues is generally found to be interesting and motivating to students.

One group of teachers from a government metropolitan secondary school displayed their well-considered insight into the effectiveness of the shift towards the inclusion of STS objectives in secondary science courses when they complained that the assessment of the STS component of their courses, the social relevance report took a lot of students' time, and was not, in their opinions, particularly effective. These teachers concluded that "Instead of teaching in a context, the STS component becomes an absolute dominance for a short period of time." This add-on approach towards the inclusion of STS, which was discussed by Fensham (1990), is not sufficient for a change in the emphasis of science curricula to have the maximum chance of success. It is most effective to teach all science from the foundation of STS. One group of teachers in the South Australian study believed that it was better to use STS to provide relevance throughout all of their teaching rather than the focus upon the social relevance report. However, the above discussion of teachers' views indicates that teacher in-service and support is necessary for a greater majority of teachers to develop the confidence, understanding and attitudes required for them to help their students achieve the STS objectives of the secondary science courses effectively.

Consideration of these interviews that were conducted with Australian teachers leads to the conclusion that was stressed in previous studies of teachers' understandings and attitudes towards STS and the history and philosophy of science that it is important to focus upon certain ideas:

> Science teachers learn science through their undergraduate work in a science discipline; they must also learn about science so that they in turn can teach science not as a rhetoric of conclusions, but as a powerful form of making meaning of the world, often tentative and problematic, with an important history and social and philosophical contexts. Sustained study of history and philosophy of science by beginning teachers throughout the undergraduate science curriculum and in science teacher education courses would provide them with these contexts, and enable them to meet the needs not only of the future scientists, but of the majority who will not be scientists. (King, 1991, p. 140)

Summary

The information obtained from the groups can be summarised under six headings, which cut across the six questions asked in the structured interviews.

1. Over 80 per cent of the teachers in this survey believed that it was important to include STS objectives in secondary science courses in South Australia, since discussion of the issues of STS provided motivation for learning by "making the links", or contextualising the scientific work that was studied. Teachers in five of the interview groups from a variety of schools further believed that STS education prepared students for their lives in society by enabling them to participate in informed debates on the direction of science and technology.

2. Incorporation of STS into South Australian secondary science courses has occurred at both the senior and junior secondary levels. The Year 12 PES Chemistry and Year 12 PES Biology students now have a social relevance report as a component of the assessment of the course. At the junior secondary level, 70 per cent of teachers included STS within some course units as discussions or activities, or as excursions to provide students with the opportunity to observe science and technology at work in society. The degree of success in the effective inclusion of STS in science courses would appear to depend on the attitudes and knowledge of the teachers. Younger teachers who had discussed STS in their undergraduate courses, and experienced teachers who were flexible in their approach to learning and teaching, achieved a greater degree of success with assisting their students to meet the STS objectives of the re-developed courses. Some of the more experienced teachers regarded STS as an intrusion, and were

quite resistant to changing their traditional ways of teaching. Three groups of teachers from quite eminent and well-established government and non-government schools, by way of example, were concerned at having to vary the teaching methods and assessment that they had previously used in science courses. Teachers in eight of the interview groups from a variety of different types of schools were also concerned about not being able to cover all of the scientific concepts required at the senior secondary level, as well as meeting the STS objectives.

3. Difficulty in obtaining access to appropriate resources to use in STS education was experienced by teachers in 21 of the interview groups in this study, as adequate resources were expensive and not readily available. In addition, some of the textbooks did not have the STS component integrated into the discussion of the scientific concepts within the chapters. Three groups of teachers from both metropolitan and non-metropolitan schools believed that this problem would be overcome by increased access to a variety of resources from a centralised location. Teachers in 13 groups from a variety of schools experienced difficulty in finding the time that was necessary to research STS issues to be included in their classes.
4. Most of the groups of teachers believed that both male and female students responded well to STS. However, some teachers added that this depended on the issue that was being discussed. Six groups (two from government and non-government girls schools, three from government co-educational schools and one from a non-government co-educational school) also considered that girls responded more diligently than boys to STS, and, in fact that girls responded more diligently to all of the activities in their science courses. Teachers from three interview groups (two from non-government boys schools and one from a non-government co-educational school) found it difficult to discuss the social relevance of science with the boys in their classes.
5. Many of the teachers viewed science according to the classical model, with aspects of the method including observing, hypothesizing and testing. In ten of the interview groups, however, some of the teachers' views of science varied from the traditional. The views of these teachers from both government and non-government co-educational and single-sex schools included insights into the nature of science as a human activity, which could not, therefore, always be entirely objective. The more-stereotyped responses of the other teachers did not include consideration of objectivity or subjectivity in relation to science, and these teachers believed that science was sometimes still presented as a fairly stable and objective body of knowledge. Teachers from three groups considered that there was a need to stop students believing in a simple technological fix to every problem.
6. Seventeen groups of teachers believed that there was a need for in servicing of teachers in relation to STS education, and teachers in nine of these groups wanted the in-service courses to focus upon increasing their understanding in this area. These teachers viewed the workshops on National Statements and Profiles as being unsatisfactory, on the whole. Other issues which teachers also considered to be significant included: the lack of time to locate appropriate information on STS; the great expense of resources; and insufficient access to a variety of appropriate resources. Teachers from nine of the interview groups believed that appropriate teaching methodologies for the incorporation of STS issues into undergraduate courses would also be an important issue for consideration in relation to the

successful implementation of the curriculum change that involved the inclusion of studies of STS in secondary science curricula.

The structured interview section of this study has highlighted the urgent need for the provision of in-service courses for Australian secondary science teachers. The need for in-service courses in relation to STS was considered to be significant by the large majority of both experienced and relatively new teachers who were interviewed during this study. The teachers believed that they needed to increase their understanding of STS, and the requirement for constant updating of knowledge in this ever-changing area was stressed. The findings of this study showed that the inadequacy of some teachers' understanding of STS had affected their students' understanding. This effect was clearly shown in their matriculation examinations according to one of the teachers. This teacher, who had been a marker of examination papers, believed that some of the students could not answer the human genome question, since their teachers did not understand this issue, and hence did not explain it well to the students.

This chapter commenced with the contention that teachers are only able to teach effectively when they understand the subject matter well. The interviews discussed in the chapter revealed quite a diverse range in teachers' understandings of the nature of science, the issues of STS and the ways in which scientists work. Teachers' views on the curriculum shift towards STS also varied greatly from favourable to quite unfavourable in relation to STS. Consequently, an important issue for consideration is whether the views, beliefs and attitudes of South Australian teachers are sufficiently strong and coherent to enable the teachers to discuss the issues of STS in their lessons in a manner which provides an appropriate opportunity for students to develop strong and coherent views on STS. Furthermore, if teachers' views on STS are strong and coherent, teachers are likely to be more able and more confident to meet the challenges presented by the shift towards the inclusion of STS objectives in secondary science courses in South Australia. The present chapter has provided qualitative discussion of the views of teachers. In the following chapter, the results of measuring students', teachers' and scientists' views on STS and comparisons between the strength and coherence of the STS views of these three groups are discussed.

As discussed in this chapter, some of the older teachers in the interviews felt rather insecure about including discussions of STS issues in their classes, and suggested that this watered down the content. Ziman (1980) decried this claim by science teachers who had a poor understanding of the benefits of the STS approach to science teaching. He argued that in STS science, traditional science content is not watered down, but is embedded in a social, technological context. Hence, the study of science is rendered more meaningful to the students, and the content is generated logically by the context on a need-to-know basis.

13

The Coherence of Students', Teachers' and Scientists' Views on STS

The strength and coherence of young people's views, beliefs, attitudes and opinions towards STS issues are important considerations for educators and curriculum designers who aim to empower students to meet the challenges of the future. One of these challenges involves the role played by the Australian public in debate and decision-making with regard to the use of science and technology to shape a sustainable future for the nation. For curriculum design and teaching to prepare students to take an informed role in debates on STS issues, it is important to acknowledge that students construct their views, beliefs, attitudes and understandings by building on a series of assumptions and opinions obtained from their parents and from the mass media. Moreover, the views, beliefs, attitudes and understandings already held by students influence classroom teaching and peer group discussion, and thus determine the quality of learning that takes place (Biggs, 1996). Consequently, this investigation of the STS views of students, teachers, and scientists, which is discussed in this chapter, has a great deal to offer to teachers and curriculum designers.

In this Australian study, students' views on STS were collected and measured using a scaled instrument. The strength and coherence of students', teachers' and scientists' views on STS were assessed by measurement using the scales constructed in the course of the study. The scales were validated by comparing the calibrated scale values with the views of experts. In this way, strength and coherence are indicated ultimately by agreement between what the respondents thought and what the experts thought. However, during the calibration of the scales, they were also tested for internal consistency by the procedures of Rasch scaling employed. As a consequence the scales that were developed were considered to be independent of the large sample of students who were used to calibrate the scales, and independent of the particular items or statements included in the scales. Moreover, the scales were constructed to be interval scales, so that they could be employed to measure change over time.

Measurement of STS Views Using Scales

Teachers can only teach STS views effectively when they have strong and coherent views towards STS. Thus at this early stage of the shift towards the inclusion of STS objectives in secondary science courses in South Australia, it is important to examine teachers' views towards the issues of STS as well as students' views. As Kimball (1968) suggested, the implications of this issue usually centre on changes in education programs. Consequently, it is important to consider the understandings of the nature of science and the philosophy of science held by teachers at a time of change in the science curricula, and the development of new programs in science education.

Teachers' views play an important role in forming students' views towards science (Evans and Baker, 1977). It is important to ask if science teachers' views of the philosophy of science are sufficiently coherent to enable them to present a balanced view of the nature of science in contemporary societies. This balanced view demands coherent attitudes and understandings with regard to the nature of science, the nature of scientific knowledge, the characteristics of scientists, and the interrelations between science, technology and society, as is argued in this work. King (1991) agreed with the need to consider teachers' views towards the nature of scientific knowledge, as well as of the history and philosophy of science when he wrote:

> Clearly the teacher plays a key role in providing an image or 'implicit philosophy' of science which is interesting and accessible to students as well as representative of the tentative and problematic nature of scientific knowledge, and some knowledge of the history and philosophy of science would surely help to achieve this. (King, 1991, p. 136)

Not only were the implications of teachers' STS views and beliefs considered to be significant in this present study, but as Pomeroy (1993) has argued it was important to undertake comparisons between the beliefs of scientists and those of secondary science teachers. The need for these comparisons arises from three issues and concerns:

> 1) the literature contains conflicting opinions and data as to the current philosophical status of scientists and science teachers;
> 2) questions of whether the philosophers and luminaries of science represent the same view of science held by scientists; and
> 3) a sense that the relative philosophical stances of scientists and teachers might provide interesting implications for science teacher education. (Pomeroy, 1993, p. 261)

Pomeroy's study explored the beliefs and attitudes of samples of American research scientists and teachers. This South Australian study measured and compared the views of scientists, teachers and students in relation to STS. In a way which is similar to the 1993 American study, this South Australian study had to consider the philosophical tensions which existed between the logico-positivist description of science often presented in textbooks and the newer, post-positivist philosophies of science.

In order to examine whether the traditional ideas of the philosophy of science persisted among science teachers and research scientists, Pomeroy developed a 50-item survey instrument using a Likert-scale response format for items based upon the ideas of philosophers including Popper, Polanyi, and Kuhn. Thus, this South Australian study is substantially different from Pomeroy's study, in that it measured STS views using a scaled multiple-choice format with items originally developed by Aikenhead, Fleming and Ryan (1987) in order to reduce ambiguity in the meanings perceived by students who responded to the questionnaire.

An outstanding feature of this present study is that rather than leading to a essentially qualitative indication of students,' teachers,' and scientists' views on STS, this study culminated in the measurement of STS views using scales which were developed for the study. The anomalies and apparent disagreements in the findings of studies on student', teachers' and scientists' views in relation to both STS and the nature of science highlighted the need for accurate measurement of STS views. Consequently, valid and reliable measurement of views on the issues of STS was sought in this study by the development of scales. The results of this part of the South Australian study are presented and discussed in this chapter.

Mean Scale Scores

The mean scale scores for students, scientists and teachers for the *Science*, *Society*, and *Scientists* scales are presented in Tables 13.1, 13.2 and 13.3 respectively.

Science Scale

It can be seen from Table 13.1 that the mean score for teachers on the *Science* scale is substantially higher than the mean score for scientists. The mean score for scientists, in turn, is higher than the mean score for students. The higher scores for teachers on the Science scale might indicate that teachers have had a greater opportunity to think about the issues of STS than scientists have. This has been particularly true in recent years, since there has been an increasing shift towards the inclusion of STS objectives in secondary science curricula in Australia, and, in fact around the world (see Chapters 1 and 3). In Table 13.1, for the student data, as discussed in Chapter 5, the standard errors were calculated using a jackknife procedure with the WesVarPC program (Brick et al, 1996). This type of calculation allowed for the fact that a cluster sample, rather than a simple random sample was used in this Australian study of students' views.

Table 13.1 Mean scale scores, standard deviations, standard errors and 95 per cent confidence intervals for the mean - Science Scale

Group	Count	Mean	Standard Deviation	Standard Error [j]	95% Conf Int for Mean
Students	1278	0.317	0.548	0.033	0.251 to 0.383
Scientists	31	0.516	0.506	0.091	0.334 to 0.698
Teachers	110	0.874	0.444	0.042	0.792 to 0.958

j : jackknife standard error of mean

Reflection upon the sociology of science provides a further possible explanation for the discrepancy between the level of the STS views of scientists and teachers. Scientists interact and exchange ideas in unacknowledged collegial groups (Merton, 1973), the members of which are working to achieve common goals within the boundaries of a particular paradigm. Scientific work also receives validation through external review, and the reviewers have been promoted, in turn, through the recommendations of fellow members of the invisible collegial groups to which they belong.

Radical ideas and philosophies are, therefore, frequently discouraged or quenched. The underlying assumptions of STS are that science is an evolutionary body of knowledge that seeks to explain the world and that scientists as human beings are affected by their values, and cannot, therefore always be completely objective (Lowe, pers. comm., 1995). STS ideas might be regarded by many traditional scientists as radical or ill founded. Thus, scientists in this study appear not to have thought about

STS issues enough, since they might not have been exposed sufficiently to informed and open debate on these issues.

The suggestion that scientists construct their views from input they receive throughout their lives is also a possible explanation for the level of scientists' views being lower than that of teachers. The existing body of scientists in senior positions have received, in the greater part, a traditional science education. During these scientists' studies, science was probably depicted as an objective body of fact, and the ruling paradigms within which they, as students, received their scientific education defined the problems that were worthy of investigation (Kuhn, 1970a).

Educational establishments are therefore responsible for guarding or maintaining the existing positions or views on the philosophy, epistemology and pedagogy of science (Barnes, 1985, and Chapter 6).

A comparison of the standard deviations of the teachers' and scientists' mean scores shows that the range of scientists' views on STS on the *Science* scale is greater than the range of teachers' views. The standard deviation of students' views demonstrates that students' views on STS range more widely than the views of either scientists or teachers.

Some scientists have more coherent views on STS than others. This could be due to the different educational backgrounds of some of the younger scientists, since STS has been included as a component of some undergraduate science courses in Australian universities such as Griffith University from 1974. It is also possible that some scientists have considered STS issues, while some others have just continued with their fairly routine problem solving and research. Since humans construct their understandings from their life experiences, it would be expected for teachers to have a smaller standard deviation of views on STS than scientists do.

Society Scale

On the *Society* scale, teachers again have a much higher mean score for their views on STS than scientists, as shown in Table 13.2. Students have a lower mean score than either scientists or teachers.

Table 13.2 Mean scale scores, standard deviations, standard errors and 95 per cent confidence intervals for the mean - Society Scale

Group	Count	Mean	Standard Deviation	Standard Error [j]	95% Conf Int for Mean
Students	1278	0.210	0.590	0.028	0.154 to 0.266
Scientists	31	0.339	0.499	0.090	0.159 to 0.519
Teachers	110	0.695	0.497	0.047	0.601 to .789

j : jackknife standard error of mean

Also in a similar way to the results for the *Science* scale, on the *Society* scale, the standard deviation of students' views was slightly greater than the standard deviation of scientists' and teachers' views. This indicates a greater range of the young peoples' views on these issues, which is perhaps to be expected for people at this stage of the development of both their scientific understanding as well as their understanding of STS issues (Driver, 1990). Furthermore, in a way that is similar to the results for the *Science* scale, for the *Society* scale, the standard deviation of scientists' views is marginally greater than the standard deviation of teachers' views. In this case, however, the magnitude of the standard deviations for teachers' and scientists' views is quite similar and not significantly different.

Scientists Scale

Again for the *Scientists* scale, the same pattern of relative mean scores is observed. Teachers have the highest mean score, followed by scientists with the second highest score, and students with the lowest score of the three groups as shown in Table 13.3. For this scale, unlike the *Science* and *Society* scales, scientists have the largest standard deviation. The standard deviation of teachers exceeds that of the students involved in the study. Thus, of the three groups of respondents, scientists have the greatest range of views on the characteristics of professional scientists. This might be due to the suggestion made in the above discussions of the mean scores and standard deviations for the three groups of respondents on the *Science* and *Society* scales that peoples' life experiences influence their views, understandings and attitudes towards the issues of STS. Thus, the diverse experience scientists have of fellow scientists' characteristics could make it difficult for them to decide between the alternative responses to statements on the characteristics of scientists.

Table 13.3 Mean scale scores, standard deviations, standard errors and 95 per cent confidence intervals for the mean - Scientists Scale

Group	Count	Mean	Standard Deviation	Standard Error [j]	95% Conf Int for Mean
Students	1278	0.408	0.582	0.032	0.344 to 0.472
Scientists	31	0.596	0.932	0.167	0.262 to 0.930
Teachers	110	0.965	0.733	0.070	0.825 to 1.105

j : jackknife standard error of mean

The fact that on the *Scientists* scale, the standard deviation of scientists' views exceeds that of the teachers' views substantially, also indicates that some scientists had coherent views on STS issues, whereas others had just continued with their scientific work, or problem-solving within the boundaries of the prevailing paradigm, without considering the social relevance or context of science and technology. These relatively large standard deviations showed that the spread of scientists' views was greater than the spread of teachers' views. It would appear that some scientists were positivistic in their ideas, and others viewed the philosophy of science from more of an STS and post-positivistic perspective (see Chapter 2).

Among this group of scientists there were some who couldn't answer several of the questions, perhaps because they had not thought about the issues sufficiently or as discussed above, could not decide between alternative responses. This was recorded as a 0 response, and contributed to the wide spread of scores.

The Strength and Coherence of Respondents' Views on STS

The measurement of the strength and coherence of respondents' views on STS which was accomplished during this present study is important, since consideration of students' and teachers' views and understandings in relation to the objectives of new curricula is a crucial component of an investigation of a curriculum change. The standard deviations of the three groups of respondents also provide useful information. Comparisons of the views of respondents from this study as well as from studies with similar groups of respondents are also important in order to suggest reasons for the differences in mean scores and standard deviations of the respondents' mean scores.

The Coherence of Students' Views on STS

The evidence emerging from this South Australian study is that students had STS views which were of lower strength and coherence on the three scales than those of the teachers or scientists. However, the students still had quite strong and coherent views on STS when compared with the views of the experts, which were used to validate the scoring of the items used during this study. This finding is to be expected, since it is discussed in Chapter 11 that when compared with two other groups of young people, South Australian students had more favourable STS views on a selection of issues. The standard deviations of the students' views showed that South Australian students had a greater range of views on STS on the *Science* and *Society* scales, than either teachers or scientists. However on the *Scientists* scale, the standard deviations indicated that students had a smaller range of views on the STS issues than either the scientists or the teachers.

These findings in regard to students' views on STS are of particular benefit to teachers, educators and those involved in curriculum design. Two of the research workers who developed the VOSTS inventory, from which items were selected and scaled for the present study, supported this statement on the potential benefits of the findings of this present study. They wrote that:

> As science programs continue to emphasize an understanding of the nature of science, educators and researchers need ways of assessing students' views on a wide range of science-technology-society (STS) topics. (Ryan and Aikenhead, 1992, p. 559)

Ryan and Aikenhead believed that the data collected using the VOSTS items with high school students would guide the design of lessons and curricula and provide teachers with a valid way of assessing students' views on STS issues. However, as it is argued in Chapter 5, the conclusions and recommendations arrived at from this present study, which used an instrument to gather students' viewpoints on STS, would be significantly stronger than previous studies as a consequence of adding a measurement component. This study thus represents a considerable advance on previous studies that assessed students' STS views, since these studies were largely qualitative in nature. This present study has also improved on previous quantitative studies in the way the validities of both the original VOSTS instrument and the scaled VOSTS items in the questionnaire used in the present study were established. The techniques for establishing the validity of the original VOSTS items are discussed in Chapter 7.

An earlier, largely qualitative study (Zoller et al, 1991) in British Columbia, by way of example, assessed the STS beliefs and positions of Grade 11 students who were enrolled in an STS course in comparison with the views of students not enrolled in the course. In the 1991 study, significant differences were found between the STS beliefs and positions profiles of the STS students and the non-STS students. However, the researchers concluded, "the goal of STS-literate students has not been achieved as yet". (Zoller et al, 1991, p. 25) The conclusion reached as a result of this Canadian study was that appropriate teaching strategies should be developed and implemented both within courses which included STS objectives, and teacher training programs, if the goals of becoming technologically or STS -literate were to be achieved.

In the Canadian study, an instrument comprised of six statements from the VOSTS inventory was used to gather students' views on STS (Zoller et al, 1991). Unlike the present study, however, analysis of the findings occurred by simply clustering like responses to organise STS profiles for the groups. The researchers in this Canadian study observed the difference in patterns of responses, rather than scores that were used in the present study to measure the strength and coherence of views. A similarity between the two studies was that one of the aims of the 1991 Canadian study supported the aims and potential benefits of both this present study and Ryan and Aikenhead's study, as discussed above. Zoller et al.'s study aimed to establish base-line data on students' as well as teachers' STS views, since STS courses taught by teachers who had strong and coherent views on STS issues could be expected to affect students' views. The authors supported the significance and potential benefits of both their own 1991 study and the present study when they argued that:

> ..the establishment of the relevant base-line students', and their teachers', STS position profiles are vital for the development of appropriate on-target responsive STS curriculum materials as well as pre- and in-service STS-oriented teacher training programmes. (Zoller et al., 1991, p. 26)

A more recent study by Yager and Tamir (1993) assessed, in a quantitative manner, the effect of an STS course on the development of positive student attitudes towards STS in a sample of 720 primary and junior secondary science students. The researchers believed that reputable science programs must generate more positive student attitudes, including attitudes towards science, expressing feelings constructively, exploring the various sides of arguments and making decisions about STS issues. Yager and Tamir (1993) contended that concern with the generation of positive student attitudes was crucial, since negative attitudes rendered the STS course objectives trivial. The well-grounded argument advanced by these authors was that:

> The focus of STS upon current issues and student questions and interests makes the attitude domain particularly important. (Yager and Tamir, 1993, p. 643)

In the 1993 study, students' attitudes were assessed using 18 items from the National Assessment of Educational Progress (1978) with a five-point Likert-type scale (Yager and Tamir, 1993). The findings of the study were that:

> ..students have gained substantially more than their non-STS counterparts in the attitude domain. The difference found in attitude was high, 1.6 standard deviations. (Yager and Tamir, 1993, p. 656)

It is of significance that this increase in students' attitudes through the STS approach occurred without any loss in content learning. The finding of stronger and more coherent attitudes for these students in the 1993 study agrees with the finding of quite strong and coherent attitudes in students in the present study. Perhaps the fairly strong and coherent STS views of South Australian students are an indication of the efficacy of the shift towards the inclusion of STS objectives in secondary science courses in South Australia. However, the students in the earlier study were of a different age group, and this might influence the comparisons that could be made between the findings of the two studies.

The Coherence of Teachers' Views on STS

It would appear that teachers had thought more about STS issues than scientists had. In addition, it was possible that scientists had constructed their views from conflicting input that they received during their lives. However, perhaps the consistency and coherence of teachers' views was due to the nature of the teacher groups who responded to the survey. The teachers who volunteered most willingly to complete the survey were quite young. Young teachers were often more likely to participate in open debate than their older colleagues who held firmly entrenched views. In recent years, teacher education courses in science have moved to include a component on STS ideas. However this "add on" approach (Fensham, 1990) is a long way from a teaching focus that uses STS as a foundation upon which to build students' understandings of science, so further development is needed in these teacher education courses.

The standard deviation, and therefore range of teachers' views on STS, is not as great as the range of scientists' views. The smaller standard deviations for teachers' scores on the three scales, relative to the standard deviations for scientists' scores might be due to young teachers' openness to debate, coupled with the recent changes in teacher education courses. This has resulted in the development of fairly coherent views on STS by the science teachers surveyed in this study. Teachers' higher mean scores on all three scales also support this suggestion.

The high level of the scores for teachers' views on STS is unexpected on the basis of published findings of previous studies. Students' and teachers' views on the nature of science were assessed in the United States by Lederman (1986), for example, using the *Nature of Scientific Knowledge Scale* (Rubba, 1976), and a Likert scale response format. Unlike the findings of the survey in this South Australian study, which used scales to measure students' and teachers' views and understandings in relation to STS, this American study found misconceptions in preservice and in-service teachers' views and beliefs about STS issues (Lederman, 1986). However, the use in Lederman's study of comparison with the most commonly accepted attributes as a way to judge misconceptions was vague, and raised serious questions in regard to the validity of his instrument. The instrument used in this present study overcame this problem, since the validity was established first by testing the fit between the data and the Rasch scale as well as by an independent scaling of the instrument by seven experts (see Chapter 7).

The results of another survey (Duschl and Wright, 1989) in the United States of teachers' views on the nature of science and STS issues, led to the assertion that all of the teachers held the hypothetico-deductive philosophy of logical positivism (see Chapter 2). Thus, the authors concluded that commitment to this view of science explained the lack of effective consideration of the nature of science and STS in teachers' classroom science lessons. A reason suggested was that teachers of senior status probably received instruction and education in science that did not include any discussion of the nature of science. This explanation concurs with the explanation offered of the responses of teachers to questions on the nature of science in the structured interview component of the South Australian study (see Chapter 12).

A further possible explanation for the finding of gaps in studies over the past 20 years on teachers' understandings of the nature of science and STS is that some teachers might have relied on text books to provide them with ideas and understandings for their science lessons. It appears that these textbooks contained very little discussion of the nature of science or STS issues. This suggestion was supported by an examination by Duschl and Wright (1989), of textbooks used by teachers, since this 1989 study showed that the nature of science and the nature of scientific knowledge were not emphasised in these books. Although most of the text books began with an attempt to portray science as a process of acquiring knowledge about the world, the books failed to give any space to a discussion of the history of the development of scientific understanding, the methodology of science, or the relevance of science for students' daily lives. Gallagher (1991) suggested that these depictions of science were empirical and positivistic and that most teachers believed in the objectivity of science. In regard to the reasons for this belief Gallagher reached the cogent conclusion that:

> Science was portrayed as objective knowledge because it was grounded in observation and experiment, whereas the other school subjects were more subjective because they did not have the benefit of experiment, and personal judgments entered into the conclusions drawn. In the minds of these teachers,

> the objective quality of science made science somewhat 'better' than the other subjects. (Gallagher, 1991, p. 125)

It is possible that the finding, in the present study, of strong and coherent views, beliefs, and attitudes in regard to STS held by teachers is due, at least partially, to the shift towards the inclusion of STS issues and social relevance in science text books. Discussions with South Australian senior secondary science teachers indicated that the science textbooks used in secondary schools now included examples and discussions of the social relevance of science in many instances.

The traditional inaccurate and inappropriate image of science has been attributed (Gallagher, 1991) to science and teacher education courses, which placed great emphasis upon the rapid coverage of a large body of scientific knowledge, but gave prospective teachers little or no time to learn about the nature of science or to consider the history, philosophy and sociology of science. Fortunately, this situation has now changed, to an extent, in increasing numbers of tertiary courses. The coherent views of South Australian science teachers might be due in part to this change in the emphasis of tertiary courses.

Comparison of the Mean Scores for the STS Views of Teachers and Scientists

The STS views of teachers in this South Australian study were stronger and of greater coherence than the views of scientists on all three scales**.** In a similar way to the South Australian study, Pomeroy's (1993) American study also used a well-validated survey instrument (Kimball, 1968) to explore the views, beliefs and attitudes of a sample of American research scientists and teachers. In the analysis of the results of this American study, the views which were identified in groups of statements included: (a) the traditional logico-positivist view of science; and (b) a non-traditional view of science characteristic of the philosophy of STS. Thus, consideration of the findings and analysis of Pomeroy's study provides a useful basis for the discussion of the findings of the South Australian study.

The comparison of the responses of the American scientists and teachers showed that the scientists had significantly more traditional views of science than the teachers (Pomeroy, 1993, p. 266). In the South Australian study, the scientists would also appear to have had more traditional views of science, or certainly views that were less favourable towards STS than teachers, as shown by their lower average mean scores on all three scales. Nevertheless, since the American group of teachers included elementary school teachers in addition to secondary science teachers, a direct comparison is not possible. However, this consideration of the findings of Pomeroy's study is still extremely useful, since the difference in the mean scores of the American secondary and elementary teachers was not significant ($p = 0.2$). For questions in Pomeroy's study, which gauged the non-traditional views of science characteristic of the philosophy of STS, the views of teachers were of higher average mean score than the views of scientists, although the difference was not significant (Pomeroy, 1993, p. 266).

Pomeroy's 1993 study showed that scientists, and to a lesser extent teachers, expressed the traditional view of science quite strongly. The suggestion was advanced that these findings "add to the continuing dialogue in the literature as to the persistence of positivistic thought in scientists and educators today" (Pomeroy, 1993, p. 269). The findings of this present Australian study appear to indicate that, by way of contrast, South Australian science teachers held views of science that were strong and coherent towards STS. Thus, many Australian teachers did not hold the traditional logico-positivist view of science. This may well have arisen from the courses studied by South Australian science teachers, in which there has been a strong emphasis upon STS issues in the biological sciences, in contrast to the emphasis in the physical sciences that existed in former years.

An earlier American study (Kimball, 1968) which compared scientists' and science teachers' understanding of the nature of science, was similar to the present study in that it used a scale and model which were consistent with the views expressed by Conant and Bronowski (see Chapter 2). A further similarity between Kimball's scale (the *Nature of Science Scale*), Pomeroy's scale and the scale used for this South Australian study is that they all found support for their statements from the writings of the philosophers of science. However, this present South Australian study framed the statements of its scale in terms of language used by students and the views of the students. Thus, the difference lay in the fact that Kimball's and Pomeroy's items consisted of statements written exclusively in the language of the investigators after consideration of the works of the philosophers of science. Furthermore, Kimball's and Pomeroy's scales used a Likert-type response format. The *Nature of Science Scale* was scored by allocating responses in agreement with the model - 2, neutral response - 1, and responses that were opposite to responses required by the model – 0 (Kimball, 1968, p. 112).

The 1968 study also considered whether any differences in the scientists' and teachers' understandings of the nature of science might be the result of training or experience. Kimball asserted that answers to this question were needed in order to guide revision of science teacher education programs. The study compared the views on the nature of science of scientists and teachers of similar academic backgrounds and sought teachers' and scientists' views during the years after graduation. The fact that the educational backgrounds of respondents were taken into account for the comparisons made in the earlier American study highlights a limitation of the South Australian study, since, due to the restraints of confidentiality, it was not possible to gauge the academic backgrounds of respondents for comparison of the views of Australian scientists and South Australian teachers of similar academic backgrounds.

After using the *Nature of Science Scale* to measure teachers', scientists' and philosophy majors' understandings of the nature of science Kimball (1968) found from a comparison of all science majors with philosophy majors, that philosophy majors had a significantly better understanding of science than science majors. Since understanding of the nature of science is a fundamental component of coherent views on STS, the findings of this 1968 study are of significance for this Australian study of views on STS. In this Australian study, teachers were found to have more coherent views on STS than scientists. In the Nature of Science Study, teachers scored higher than scientists on seven of the eight sub-groupings, although no significant differences were found between the views of teachers and scientists (Kimball, 1968, p. 115). Furthermore, Kimball found no evidence that either the American scientists or teachers underwent any significant changes of opinion or understanding in the 12 years from graduation. This finding, coupled with the finding that philosophy students scored higher on the scale than science students led to the conclusion that the problem lay in the education of scientists and teachers. Kimball stressed that:

> .. the concept of the nature of science is fairly well established by the time of graduation from college, another argument in favour of influencing students during their undergraduate years. (Kimball, 1968, p. 118)

Indeed, it was concluded strongly that if the study of the nature of science were not included in the undergraduate years, then it would be necessary to include discussion of this issue in teacher training programs.

Further investigation is needed into whether the effect measured by Kimball in the comparison of philosophy and science majors was due exclusively to the study of the philosophy of science, or a combination of this together with an engendered appreciation of the social relevance of science. There is also a need for further study to support Kimball's interpretation of the findings of the study. Kimball's study provided a very important context for discussion of the findings of this South Australian study.

Comparison of the Mean Scores for the STS Views of Teachers and Students

The views of teachers were found to be stronger and more coherent on all three scales than the views of students in this present study. Previous studies involving a comparison of students' and teachers' views, beliefs, and positions on STS issues also have a worthwhile place in this discussion to highlight the meaning of the results of this South Australian study. An assessment of the pre-post positions on STS issues of students exposed to an STS-oriented course, as compared with the positions of students and teachers not exposed to this course was undertaken in Zoller et al.'s (1991) study in British Colombia. This Canadian study used a scale consisting of six questions from the VOSTS inventory (Aikenhead, Ryan, and Fleming, 1989) to compare the beliefs and positions of groups of STS-students with their teachers and with non-STS Grade 11 students. The study addressed whether the STS positions of students and their teachers were similar or different. Since the questions for the scale used in the South Australian study were also adapted from the VOSTS inventory, consideration of the results of Zoller et al.'s study is of particular interest in this discussion of the findings on South Australian teachers' and students' STS views. One of the six questions in the scale used in this Canadian study, was concerned with whether scientists should be held responsible for the harm that might result from their discoveries, and was also in the scales used in the Australian study. In the Canadian study, students' and teachers' views were compared by grouping the responses to each of the statements into clusters, which formed the basis for the analysis. The STS response profile of Grade 11 students was found to differ significantly from that of their teachers.

A critical problem in the report of Zoller's Canadian study with regard to the production of possible biases through non-random sampling and self-selection of teachers and scientists is also relevant for the South Australian study. The selection processes, which were used in both studies, might have produced some bias as a consequence of those who chose to respond being more interested in philosophical issues, or more confident about their views on the philosophy, pedagogy and sociology of science. In the South Australian study the younger teachers volunteered more readily, and this self-selection of teachers might have introduced some bias into the results.

In this present study a master scale was employed to measure the extent to which students held strong and coherent views, and it was found that the students fitted the scale model well. The South Australian students' views on STS were shown in this study to be quite strong and coherent. However, it was considered that scientists might have less coherent views, since the statements comprising the scales were developed from students' views. Furthermore, since there were fewer teachers surveyed overall, and fewer scientists again, the consequences of erratic views being held by a few teachers or scientists might have been greater.

It appears from consideration of the literature on teachers' views of the nature of science and the issues of STS that many senior secondary science teachers throughout the years have depicted science incorrectly. However, it would also appear from the results of this present South Australian study that in recent years this situation might have begun to change. In this South Australian study the STS views of secondary science teachers were shown to be quite strong and coherent. It is possible that the move towards the inclusion of STS objectives in senior secondary science courses in South Australia has precipitated the development of these stronger and more coherent views. Another possible explanation for the finding of quite strong and coherent views on STS in South Australian secondary science teachers is that the media have provided Australian citizens with the opportunity to consider and reflect upon the issues of STS. However, the structured interviews discussed in Chapter 12 showed that the results might have been due to the large proportion of younger teachers who volunteered to respond to the instrument that was used during this present study. The interviews included a greater range of both experienced and young teachers than the group that responded to the instrument in this study. It appears that the undergraduate training of science teachers has changed sufficiently to address the need created by the changed objectives, so that consideration of the issues of STS is included to a greater extent in these courses.

Summary

A significant contribution of this South Australian study to educators and those involved in curriculum development was the measurement of students' views on STS. The views of teachers and scientists were also measured. An evaluation of curriculum change necessitated close consideration of teachers' views, since teachers' views on a component of the curriculum might have affected how it was taught. Scientists' views were also measured, since the philosophy of science favoured by practicing scientists was not clear. The views of teachers were stronger and of greater coherence with the views of the experts than those of scientists and students. This was considered to be due to both the nature of the teacher groups who responded to the survey, and the fact that some of the scientists would appear not to have had the opportunity to consider these STS issues. The standard deviation of the scientists' scores for views on STS were also greater than those of the teachers, indicating that the scientists had a much greater range of views than teachers did. The standard deviations of the three groups of respondents also show that the spread of students' views is greater than that of the views of scientists, followed by teachers for both the *Science* and *Society* scales. However for the *Scientists* scale, the range of the views of scientists involved in the study exceeds that of teachers by far. On this scale, students have the smallest range of views, indicating that teachers had a wider range of views on these issues than students did.

In this chapter, the views of the South Australian senior secondary students involved in the study have been discussed. The results of measuring these students' views demonstrated a reasonable level of coherence and agreement with the scale, which was validated by experts. Students' views were not as strong and coherent as the views of their teachers. The conclusions and recommendations on the basis of these findings and the findings of analyses discussed in previous chapters should assist all of those who are involved in teaching and curriculum design in this area. These conclusions and recommendations are discussed in the next chapter.

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Conclusions

Recognition of the need for informed public debate on the issues resulting from the relationships between science, technology and society (STS) in Australia has resulted in a shift towards the inclusion of STS objectives in senior secondary science curricula. In this study it was considered that valid measurement of students' views on STS would inform the development of appropriate courses and curricula for secondary science subjects as well as in-service and pre-service courses for teachers.

The Design of the Study

A major aim of this study was to develop scales, in which each response to the items was assigned a numerical value, to measure the strength and coherence of views on STS. The two problems presented in such quantitative studies that use scales are: (a) the consistency of the scaling, and (b) the validity of the scaling. The consistency of students' views on STS was established using Rasch scaling with the QUEST test analysis system (Adams and Khoo, 1993). Validation for the coding of the alternate responses in the scales was provided by comparing the scores supplied by a panel of seven experts with the scores that were derived from a review of the literature. Thus the scales developed during this study enabled a valid measurement of the strength and coherence of views of students, teachers and scientists as compared with the views of the experts. The South Australian students' views on a selection of STS issues were also compared with the views of two other groups of young people.

The data collected with the scales were examined using statistical techniques. First, the data were analysed in order to address the research questions by using the Statistical Package for the Social Sciences (SPSS) after scoring with the QUEST statistical package. This analysis sought to identify the factors that affected the strength and direction of students' STS views. Secondly, the master scale obtained using QUEST was used to compare the STS views of students, teachers and scientists. The standard errors of the mean scores for students' views were calculated using the WesVarPC program (Brick, et al., 1996). Finally, since the data were nested at two levels, multilevel analysis using hierarchical linear modelling (HLM) (Bryk, et al., 1994) was used to examine the effects of the variables at the student-level and the school-level, as well as interactions between the effects at these two levels. The effects of student and school variables on the strength and coherence of students' views on STS, the students' liking of science and the students' expectations to study science at the university level were examined.

It was considered in this study, that science teachers' views on STS, as well as the teachers' beliefs, concerns and understandings in relation to the shift towards the inclusion of STS objectives in secondary science curricula in South Australia exerted a major influence on the way they presented the social relevance of science and the nature of STS issues to their students. Thus in addition to the use of scales to measure respondents' views in this present study, group interviews were conducted with teachers to consider teachers' views, concerns and understandings in relation to the shift towards STS.

Results of the Study

In this section the results of the present study are discussed by addressing each of the research questions that were advanced in Chapter 4, in order to present a clear description of the key findings. This section provides a condensed account of the extensive evidence, which emerged from the structured interviews, and analyses of data gathered by the instruments in this study.

1. **Do students as a group have strong and coherent views on STS? What are the strength and the coherence of students' views in relation to STS?**

In this present study, Rasch scaling was used to show that students as a group had coherent views on STS, in that they conformed to a three underlying dimensions with strength and coherence in regard to STS. It was shown that responses to each item could be scored on a five-point scale.

The strength and coherence of respondents' views on STS was also indicated in this study by how well respondents' views agreed with the views of the experts, since the scales used to measure respondents' views were validated by comparing the item scale values with those assigned by the experts. The evidence from this study showed that students' views on STS were meaningful and consistent when compared with the views of the experts.

This finding was expected on the basis of a comparison in this present study between the South Australian students' views on a sample of STS issues and the views of both another group of Australian students and a group of Canadian students. In these comparisons, it was demonstrated that South Australian students held more favourable views on the selected STS issues than students in either of the other two groups.

The range of the students' views in the South Australian study was greater than that of teachers and scientists on the *Society* and *Science* scales, but not so for the *Scientists* scale. The base-line data provided by this present study should assist teachers and curriculum designers both in the development of appropriate, on-target courses and curriculum materials, as well as an opportunity to assess change over time in students' views.

2. **Do student-level variables relating to the study of science at secondary school including: (a) perceived academic performance in science, and (b) liking of science, affect the strength and coherence of students' views towards STS?**

Students' perceived academic performance in science was found to be related to the strength and coherence of students' views on STS. On all three scales, the STS views of those students who gained better marks in science than in most other subjects were stronger and more coherent than the STS views of students who gained worse marks for science than in most other subjects.

Examination of the results for this study also showed a relationship between the strength and coherence of students' views on STS and their liking of science. Those students who liked science more than other subjects had consistently stronger views on all three scales than students who liked science either the same or less than other subjects.

The finding of a relationship between perceived high academic achievement in science and strong and coherent views on STS highlights a consequence of the inclusion of STS objectives in secondary science courses. Examination of the results also raises indirectly the contention that the inclusion of the discussion of STS issues in secondary science classes improves students' liking of science, although this relationship was not tested directly in the analyses reported.

3. **Do students in different areas of science differ in their views in relation to STS? How do the strength and the coherence of the views on STS of students in the publicly examined Physics, Chemistry and Biology (PES) subjects and School Assessed Science (SAS) subjects compare?**

The STS views of students of the publicly examined subjects, Chemistry, Biology and Physics were consistently stronger and more coherent than the scores of students taking the school assessed subjects Biological Science and General Science. Since it has been argued in this work that the development of strong and coherent views on STS is a requirement for all citizens to make informed decisions in relation to STS issues, this low level of views on STS held by students of Biological Science and General Science is of concern. For many of these students, inclusion of STS objectives in secondary SAS science courses might be their only opportunity for the development of strong and coherent views on STS within the formal educational environment. Furthermore, courses such as Biological Science and General Science lend themselves to the inclusion of the discussion of STS issues, because they are not usually subjects that have such stringent requirements to cover all of the content considered necessary for entry to university as the PES subjects do.

Since a social relevance report is an assessed component of both Chemistry and Biology, it might well be argued that the finding, in this present study, of strong and coherent STS views of students who studied these subjects might be at least partially due to the shift towards STS in these secondary science courses. However, since the Physics curriculum did not include a social relevance report, it is difficult to draw strong conclusions in regard to the effect of the inclusion of STS objectives in specific science courses on the strength and coherence of the STS views of students of these courses. This difficulty is exacerbated by the fact that 11 per cent of the Physics students who responded to the scales in this study were known to have been required, by their teacher, to write a social relevance report during their Year 11 studies. Moreover, a very substantial number of the Physics students would also have studied Chemistry or Biology.

4. **Do students' expectations of future participation in science that include: (a) expected years of further education, (b) expected inclusion of science subjects in further education, (c) expected science and non-science courses for further education, and (d) expected future occupations, influence the strength and coherence of students' views on STS?**

Examination of the results of this present study showed that strong and coherent views towards STS were correlated with students' expectations to continue with further education after the completion of secondary school. Students who expected to participate in three to four years of further study had stronger and more coherent STS views on the three scales than students who either expected between one and two years of further education, or didn't expect to continue their education.

Subsequent consideration of the data demonstrated that this further education did not necessarily have to include science subjects. This is important since, with the wide use of technology in the contemporary Australian society, those involved in the areas of law, economics and politics are frequently involved in making decisions concerning STS issues.

Expected courses for further education were also found to be related to the strength and coherence of students' views on STS. Those students who expected to study in the areas of the health sciences, engineering, technology or applied science had STS views that were of a consistently high level on all three scales. This is beneficial, since people in these occupations are likely to be involved frequently in making decisions in regard to STS issues. However, the finding of views of low strength and coherence in students expecting to study towards occupations in business, commerce, architecture and agriculture is of concern. These views might prejudice effective decision-making by these students in their future work environments.

Students who expected to enter careers as professionals had strong and coherent views on STS on all three scales. The strong and well-directed STS views held by this group might assist them to make socially responsible decisions in relation to STS in future years. It was of concern, however, that the STS views of students who expected to work as managers were of a particularly low level on the *Scientists* scale. It is possible that people from this group perceived economic considerations to be more important than the characteristics of scientists and how they worked. The low level of strength and coherence of the STS views of this group might have a negative effect on their ability to make effective decisions in relation to STS issues.

5. **What is the effect of variables related to home background of students, including mother's and father's occupations, on the strength and coherence of students' views towards STS?**

Students from backgrounds of higher socioeconomic status (SES) in terms of father's occupation were found to have stronger and more coherent views on STS on the *Society* and *Science* scales, but not the *Scientists* scale, than students of backgrounds of comparatively lower SES. However, no significant relationships were found on any of the scales for the effect of the SES of mother's occupation on the strength and coherence of students' views on STS. Furthermore, it was found that students from lower SES backgrounds liked science less than students from higher SES backgrounds.

6. **Are there relationships between school-level variables that include:**
   a) **sex of school (co-educational, single-sex boys and single-sex girls),**
   b) **type or governing body of school (government, independent or Catholic),**
   c) **school location (metropolitan and non-metropolitan), and**
   d) **socioeconomic status of school (average socioeconomic status of father's occupation) and the strength and coherence of students' views towards STS, students' liking of science, and students' expectations of further study of science after the completion of secondary school?**

There was a significant relationship between the average SES of a school, in terms of average SES of father's occupation for a school, and the strength and coherence of students' STS views on the *Science* scale. The higher the average SES of a school, the stronger and more coherent were the STS views of students attending that school on the *Science* scale.

An interesting effect of school type, which was found in the analysis using HLM, was that students in non-government schools liked science more and expected to engage in the further study of science more than students in government schools. There might have been differences in the way science was taught in these two types of school. Furthermore, the laboratories might have had better resources and might have been used more effectively in non-government schools than in government schools. This relationship is not inconsistent with the stronger and more coherent views on the *Science* STS scale.

The sex of school attended was found to have no direct effect with the analysis using either HLM or the more conventional forms of statistical analysis of students' views on STS. Moreover, there were no differences observed between the strength and coherence of the STS views of students in metropolitan and non-metropolitan schools. These relationships did not take into consideration the multi-level nature of the data.

7. Do interactions between multi-level variables influence
  a) the strength and coherence of students' views on STS,
  b) students' liking of science, or
  c) students' expectations of further study, particularly of science?

Since the data in this present study were nested, with students grouped into schools, it was considered important to examine the data using HLM. This represented a considerable advance of this present study over previous studies that did not use multi-level modelling. The use of HLM allowed the formulation and testing of hypotheses about cross-level effects and the consideration of both within- and between- school components (Bryk and Raudenbush, 1992).

Examination of the data showed that there were no interactions between multi-level variables affecting the coherence of students' views on STS. However, there was an interaction between school sex and father's occupation, which affected student's liking of science. In co-educational schools, students from backgrounds of high SES liked science slightly more than students from backgrounds of relatively low SES. In boys' schools, students from backgrounds of high SES (in terms of average SES of father's occupation) liked science more than students from backgrounds of lower SES. Girls schools, however, appeared to be catering to a greater extent for equity, since there was little difference in liking of science for comparisons between students of high and low SES backgrounds.

Furthermore, an interaction between school sex and average SES of student's father's occupation for schools was found to affect students' expectations to include science subjects in further education after school. In boys schools and co-educational schools, students from higher SES backgrounds had greater expectations to continue with further study of science at university than students from lower SES backgrounds. It is interesting that in a similar way to the influence of school sex on liking of science, girls' schools also provided for greater equity in regard to expectations for future study of science at university. In girls schools there was very little difference in the expectations of students from different SES backgrounds in regard to future university studies and the study of further science.

8. Is there a relationship between the sex of students and the strength and coherence of students' views towards STS? Do males and females differ in their views towards STS?

There have been great changes in social expectations of women in modern societies as well as academic and employment opportunities. Since differences between the sexes in attitudes to science have also been found in an Australian study (NBEET, 1994), it was considered important, in this present study to see if there were significant differences between the sexes in views towards STS. A substantial number of gender-related responses to STS were found. The responses where there was a significant difference between the views of males and females related to the human element of science. More females than males believed, by way of example that scientists varied in their individual characteristics such as objectivity, open-mindedness and logic. The findings from this study supported arguments in the literature that females achieved greater understanding of, and related extremely well to science teaching that emphasised the human face of science. Consideration of the effects of science and technology on the quality of life in society rather than just on the standard of life featured in the views of a significantly larger number of males than females. Hence, this study showed that males and females differed in their views on STS.

In addition, this study found that there was a relationship between the sex of students and the strength and coherence of students' views on STS. The STS views of males were not as strong and coherent as those of females. Significant differences on all three scales between the strength and coherence of the STS views of males and females were also found by examination of the data using SPSS and WesVarPC. For the analysis using HLM, significant differences between the sexes in views on STS were shown for the *Science* and *Scientists* scales, but not on the *Society* scale.

Further examination of the data with SPSS, WesVarPC and HLM indicated no significant sex effects with regard to students' expectations to include science in their further education after the completion of secondary school. It was shown, however that male students liked science more than female students. Since as discussed in Chapter 10, female students would appear to have responded positively to science teaching which included discussion of the issues of STS, the shift towards STS in the curricula of secondary science courses might be expected to increase female students' liking of science in South Australian secondary schools. However these relationships were not examined directly by using views on STS as a predictor of liking of science.

9. What are teachers' views in relation to the recent shift in the emphasis of the South Australian secondary science curricula towards STS? How do the teachers translate the STS curriculum into what happens in the classroom? What are the gaps in their views and what are the implications of this for the training of teachers?

Teachers in 16 of the 23 interview groups viewed the curriculum shift towards STS positively, since they believed there was a need to include discussion of STS issues in science classes in order to make the scientific concepts more socially relevant. These teachers suggested that in order to prepare students to take their places as vital participants in the community, it was important to make the links between science, technology and society. Discussions with some teachers centred on the provision of motivation for students by discussing STS issues.

The South Australian teachers discussed a diverse variety of teaching strategies with which they translated the STS curriculum into their classroom teaching. Many teachers used classroom discussions of STS issues as a strategy to help students to meet the STS objectives of their courses. Teachers were particularly enthusiastic about using discussions of knowledge of STS issues that students had gained from the media as a starting point for the construction of further understandings of scientific concepts.

Unfortunately, most of the teachers stressed that there was a lack of appropriate resources for teaching STS, and more than half suggested that it was difficult to find the time to research STS issues to include in their classes. The teachers suggested that access to a central resource pack and a variety of other resources would assist them in translating the STS curriculum into their classroom practice, because they believed that resources for teaching STS were very expensive and needed continual updating.

The findings of this present study supported Thomas' (1987) argument that teachers who had been trained in the traditional courses to teach pure science found it difficult to include discussions of STS issues in their science classes, because they believed this approach to science teaching questioned the absolute certainty of scientific knowledge. Moreover, many of the experienced science teachers in this present study had probably taught in basically the same way, and had used the same teaching techniques, for many years. Hence they were probably not comfortable about using innovative techniques such as role-plays, brainstorming and community-oriented projects in small groups.

The understandings of the nature of science and the nature of STS by some teachers in the interviews in this present study were found to be quite limited. It would appear that teachers with an educational background that provided them with an understanding of the interactions between science, technology and society, were quite well informed and eloquent in regard to both the nature of science and STS issues. These were mainly fairly young teachers, as well as teachers who had worked in other professions outside of teaching and more experienced teachers who had shown flexibility and openness to new teaching innovations consistently throughout their careers

It has been argued in this work that the inclusion of consideration of STS in secondary science courses certainly did not water down the content, but offered many benefits for both the teaching and learning of science. Researchers such as Ziman (1980) have argued that in science taught from the foundation of STS, the science content was embedded in a social context that provided meaning for students.

While the teachers in these interviews were concerned about demands on their time, they were generally quite supportive of the move to include STS objectives in secondary science courses. The interviews with teachers pointed to the need for the provision of effective in-service courses for teachers in relation to the STS objectives in senior secondary science curricula.

10. Do teachers have strong and coherent views in relation to STS? What are the differences in the strength and coherence of the views towards STS of secondary science teachers and their students at the upper secondary school level?

Examination of the data in the present study showed that South Australian teachers had quite strong and coherent views towards STS on the scales developed during this study. Teachers' strong and coherent views on STS might have been due to the shift towards STS in the South Australian senior secondary science curricula in recent years. On the other hand, this finding of strong and coherent STS views in teachers might have been due to the nature of the group of teachers who agreed to respond to the scales in this study.

The sample of teachers who responded to the scales in this present study differed substantially from the group in the structured interviews. Many of these teachers were quite young, and more likely to participate in open debate on STS issues than their older colleagues. Younger or more innovative teachers were more willing and enthusiastic about giving their time to indicate their views on the issues of STS. By way of comparison, the structured interviews were either conducted in the staff-room over lunch, or as part of a scheduled staff meeting, so the older or less enthusiastic teachers were more likely to give of their time to be involved in an interview than to respond to the scales in their own time. These older teachers also showed a tendency not to display their limited enthusiasm in front of their younger colleagues.

The relatively low standard deviations for the mean scores for teachers' views on the three scales indicate that teachers had fairly coherent views as a group. The range of teachers' views on STS was smaller than the range of scientists' views on all three scales. Even though the views of the teachers on the scales were quite strong and coherent, some of the teachers had relatively low scores, and none of them had perfect scores. Moreover, the group interviews with teachers showed that a substantial number of teachers did not understand the nature of science. Thus, there was room for change in the strength and coherence of the views of some teachers in relation to STS.

11. Do scientists have strong and coherent views in relation to STS? How do the strength and the coherence of teachers' views on STS compare with the strength and the coherence of scientists' views on STS?

Scientists' views on STS were consistently not as strong and coherent as the views of teachers, and were not as high on the scales as were the teachers' views. The range of scientists' views on STS was also greater than the range of teachers' views on all three scales. A particularly large range for the views of scientists compared with the views of teachers was observed for the *Scientists* scale.

Consideration of the sociology of science provides a possible explanation for this discrepancy between the strength and coherence of the views of scientists and teachers. Scientists often work in groups with other scientists to achieve common goals prescribed by the prevailing paradigm. The work of scientists is reviewed by colleagues and the promotion of scientists follows the recommendations of colleagues. Since an underlying assumption of STS is that science is a product of human beings, and hence cannot always be totally objective, the STS view of science might be regarded by some scientists as being radical or ill founded. Many scientists, therefore, might not have been able to participate in informed, open debate on STS issues.

Moreover, the educational background of scientists might have focused on the rapid transmission of a large body of scientific content without including any consideration of the nature of science and STS issues. Since peoples' views are constructed from their life experiences, it appears that some scientists might have had very little opportunity to develop strong and coherent views on STS. These scientists might have developed their views on STS from conflicting experience of education and the reality of their observations of the issues of STS as practising scientists. Thus, when scientists were required to think about these different perspectives, some scientists might not have responded to these scales in a way which indicated that their views on STS were as strong and coherent as those of the experts. It was considered that scientists might have less coherent views, since the statements comprising the scales were developed empirically from students' views. Furthermore, since only a small sample of scientists was surveyed, the consequences of erratic views being held by a few scientists were greater.

The Limitations of the Study

In discussing the methods employed in this study it is important to note the limitations of the study, since the study was conducted at a difficult time for teachers in South Australia. Secondary teachers were reacting to the extra time and responsibilities presented by curriculum changes at both the junior and the senior secondary levels. The teachers also believed that they were over-due for a pay increase in the light of the extra responsibilities imposed by these curriculum changes. Thus, in 1995, when the fieldwork was undertaken to collect the data for this study, there was industrial action by South Australian teachers whereby school teachers had been instructed by their union not to perform any extra duties apart from their basic required teaching duties. It was not possible for some principals to agree to visits to their schools for data collection for the study, since in the light of advice from the union not to undertake any extra duties, the teachers in seven schools did not agree to be involved in the interviews or to complete the instruments. It was necessary to repeat the selection procedure to provide extra schools.

The collection of a greater amount of information from teachers with respect to age, sex, educational background, numbers of years of teaching experience and further professional experience outside of teaching would have strengthened the conclusions of this study with respect to factors affecting the coherence of teachers' views on STS. However, it was not possible to obtain this information due to the constraints of confidentiality prescribed by the requirements of the ethics approvals of both DECS and Flinders University. Teachers could have been quite readily identified after the interviews and completion of the instruments if this information had been supplied. It would have been of benefit, in a similar way, to obtain this sort of information from the scientists in the study. The difference in the coherence of scientists' and teachers' views, attitudes and understandings towards STS might then have been able to be explained in terms of formal education and a variety of life experiences. Again for reasons of confidentiality, this was not possible.

The limitations of the study included the lack of a time dimension, since it was not a longitudinal study. Furthermore, it was necessary to conduct the study during the first semester of the 1995 school year so that it did not inconvenience the students' preparation for their final year exams for the South Australian Certificate of Education. Consequently, not all of the students had completed the STS component of the course. The study was also limited to South Australia.

Implications for Theory

Two of the research workers who developed the VOSTS inventory, Aikenhead and Ryan (1992), had not realised that item response theory had advanced to the point of scaling a set of student responses as undertaken in this work. These researchers claimed that it was only possible to carry out qualitative research to examine students' views on STS. This present study took up the challenge to measure students' views in relation to STS.

This study was different from previous studies in that STS views were placed on an interval scale without assuming that the use of rank scaled scores (0-4) provided interval scales. As a consequence, this study employed a much more powerful method of scaling than that used in previous studies (Rubba, Bradford and Harkness, 1996), where researchers assumed that a Likert-type scale from 0-3 was adequate. Moreover, some of the techniques of analysis used in this present study were quite new, and these coupled with the author's choice to accept Aikenhead and Ryan's challenge to measure students' views on STS resulted in substantial differences between this present study and previous studies.

In order to assess the implications for theory of this present study, it was important to consider the answers to the questions asked during the development of the scales used in this study. These questions were: (a) conceptually is there an underlying STS position; (b) theoretically does the STS literature contain a coherent view with respect to the three dimensions of STS chosen for investigation in this study; and (c) are students' views consistent with the theoretical views of the experts?

The literature reviewed for this study showed that the scholarly writings on science, technology and society contained coherent views with respect to the three dimensions of STS investigated in this study. Consideration of these views was the first method used to validate the scales. It was demonstrated by using Rasch scaling that conceptually there was an underlying position on STS. Scoring of the responses demonstrated that the scales were consistent with the three underlying dimensions that involved strength and coherence towards STS. Thus there was sufficient consistency in the nature of respondents' views on STS to enable these views to be measured during this present study. The development of these scales and demonstration in this study that they were able to be used to provide a valid measurement of respondents' views on STS represents a significant advance in the areas of both science education and educational measurement.

Implications for Practice

The findings of this study have implications for the understanding of the nature of science and STS for members of the South Australian community, since studies in STS enable students to achieve the goal of being prepared to take informed roles in debates on STS issues. The study also has implications for educational policy and curriculum planning. Students of senior secondary science subjects, which include STS objectives, were found, in this study, to have strong and coherent views on STS. However in this study it was found that students of school assessed subjects did not have strong and coherent STS views when compared with students of the publicly examined science subjects. The STS views and understandings of male students were also not as strong and coherent as those of female students. Thus, there is a need to readdress science curricula, and the way in which these curricula are taught, to enable all students to develop strong and coherent views on STS.

The implications for classroom teaching involve the determination of whether secondary science is being taught in South Australia in a manner, which enables students to develop strong and coherent views, beliefs and attitudes towards STS. The finding of low mean scores for students of fairly limited academic performance in science when compared with students of a greater level of academic performance might indicate lower levels of reading, thinking or understanding in these students. On the other hand, it might indicate a lower level of teaching the STS issues to these students in a crowded curriculum.

The finding that students in non-government schools liked science more than students in government schools might be a reflection of the teaching of science in these two types of schools. Differences in the teaching of STS issues in the two types of schools might also explain why more students in non-government schools expected to be involved in further study of science after the completion of secondary school, as well as holding stronger and more coherent views on the *Science* scale, as assessed by average level of father's occupational status associated with the school.

The structured interviews in this study revealed differences between the views and understandings in relation to STS of the fairly young teachers and the older, more experienced teachers. The younger teachers were more enthusiastic about teaching science from the STS perspective than their older colleagues, since they understood the many benefits of this approach to science teaching. The majority of these older teachers appeared to be concerned primarily with covering the content to assist their students to gain entry to university rather than giving any of their class time to the consideration of the social relevance of the concepts discussed.

During the interviews in this present study, teachers stressed the need for the provision of effective in-service courses as one of the most significant issues in relation to the shift towards the inclusion of STS objectives in secondary science courses in South Australia. It was found that these courses should focus upon the issues of STS and the nature of science. During these courses teachers should also be provided with opportunities to share ideas and experiences of successful teaching strategies to use when assisting their students to meet the STS objectives of their courses. Most importantly, it is necessary for these courses to include discussions about the nature, history and philosophy of science, since in this present study, a substantial number of practising science teachers were found to have either a limited or inaccurate understanding of the nature and philosophy of science.

The Implications for Further Research

The scales developed during this study were shown to be effective in measuring the strength and coherence of students' views on STS in order to assist the design of courses, curricula and teaching materials. They also served as a form of evaluation of this curriculum shift towards STS. Future evaluations of curriculum shifts towards STS would be strengthened by the administration of the scales both at the beginning and the end of courses. There is a need for a longitudinal study that measures students' views, perhaps at the beginning of Year 11 and towards the end of Year 12, to examine whether there are any changes in students' views during the course of two years of study of science.

The requirement to maintain confidentiality of the respondents in the present study made it impossible to collect information on teacher characteristics such as age, educational background, and area of scientific expertise from teachers and scientists. It would be very useful to relate the strength and coherence of the STS views of these respondents to these personal characteristics in order to formulate recommendations. The difficulty in obtaining information highlights the need for a study, which relates teachers' views to their educational background, age and years of experience. Perhaps confidentiality could be maintained by an independent person giving the teacher a number and collecting this information. The number would then be added to the scales responded to by these teachers.

This present study indicates that there is so much uncertainty about the views of scientists that there is a need to extend this study into the university level. Furthermore, as well as the need to provide scientists with the opportunity to consider and learn about STS issues as part of their university education, there is a need to assist teachers with the development of strong and coherent views on STS. Hence it is important to extend this study into the universities to measure the STS views of commencing students and then periodically throughout their courses. The scales, which were developed during this present study, could be used during future studies to measure the extent of the achievement of course and university objectives. The scales could also be used in the universities to compare the STS views of students from the various disciplines.

Final Comment

From 1999, all of the senior secondary science syllabi in South Australia, for both publicly examined and school assessed subjects, will include some STS objectives. While it is encouraging to see that analysis of the data from this present study has supported this move to include STS objectives in high school subjects, there are some concerns in regard to factors which might affect the successful implementation of this further curriculum shift towards STS in 1999.

Unlike publicly examined Chemistry and Biology, publicly examined Physics does not have a social relevance report as a syllabus component. Unfortunately, as has been concluded in this study, the extent to which the STS emphasis in science teaching is taken up by teachers depends upon whether or not it is assessed. As has been discussed in this work, the social relevance report was a component of the assessment of both Biology and Chemistry, and this might be why students of these subjects were found to have such strong and coherent views on STS (Souter, 1993).

It was also concluded in this present study that there was a need to provide well-planned, effective in-service courses for teachers in order to increase the chances of success of this shift towards STS in South Australia. The teacher interviews highlighted gaps in many teachers' understandings in relation to both the nature of science and the nature of STS issues. Unfortunately, at this stage, there are no plans to provide in-service courses for teachers in this area. Clearly, there is an obvious and pressing need for in-service courses of this kind.

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Appendices

Appendix 7.1 Map of respondents and item estimates (thresholds): all students on Science Scale (N = 1278; L = 10)

```
 2.0 |                                              1.4
     |
     |
     |
     | x
     | xx
     |                                              10.4     26.4
     | xxx
     | xxxxx
 1.0 |  xxxxxxx                                     2.4      17.4
     |                                              10.3     26.3
     | xxxxxxxx
     | xxxxxxxxxxxxxxxxxxxxx                        2.3      7.4      16.4     24.4
     | xxxxxxxxx                                    16.3     22.4
     | xxxxxxxxxxxx                                 1.3
     | xxxxxxxxxx
     | xxxxxxxxxxxxxxxxxxx                          14.4
     | xxxxxxxxxx                                   17.3     22.3     24.3
 0.0 | xxxxxxxxxxxxxxxxxxxx                         7.3      14.3
     | xxxxxxxxxxxx
     | xxxx                                         14.2     16.2
     | xxxxxx                                       22.2     24.2
     | xx                                           17.2
     | xxx                                          14.1     26.2
     | x                                            7.2
     | xx                                           2.2      10.2     26.1
     | x                                            1.2
     | x                                            2.1      7.1      17.1     24.1
-1.0 | x                                            1.1
     |                                              22.1
     |                                              10.1
     |                                              16.1
     |
     |
     |
     |
     |
-2.0 |
     | x
```

Each X represents 8 students

Appendix 7.2 Map of respondents and item estimates (thresholds): all students on Scientists Scale (N = 1426; L = 8)

	x				
2.0					
	x				
	xx				
	xxxx	8.4			
		13.4			
	xxxxx	20.4			
1.0		18.4			
	xxxxxx	4.4			
	xxxxxxx				
	xxxxxxx				
	xxxxxxxxx	6.4	8.3		
	xxxxxxxxx	4.3	11.4	13.3	27.4
	xxxxxxxxx	18.3	20.3		
	xxxxxxxxxxx	18.3	20.3		
	xxxxxxxxxxxxxxxxxxxxx				
	xxxxxx	6.3			
0.0	xxxxxx	6.2	11.3	27.3	
	xxxxxxxxx				
	xxx	8.2	11.2		
	xxxx	18.2			
	xxxx	11.1	27.2		
	x				
	x	4.2	6.1	20.2	
	x	8.1	13.2	18.1	
	x				
-1.0		27.1			
		4.1	20.1		
		13.1			
-2.0					

Each X represents 11 students

Appendix 8.1 Biology SAS - views on Society, Science and Scientists Scales

Group	N[a]	F[b] ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[i]
Society	1221	0.97	NS	0.220	0.580			
A-No[g]	1058			0.229	0.590			
B-Yes[h]	163			0.163	0.511	A-B	0.11	Trivial
Science	1221	2.76	NS	0.323	0.539			
A-No[g]	1058			0.337	0.549			
B-Yes[h]	163			0.231	0.463	A-B	0.20	Trivial
Scientists	1221	0.05	NS	0.411	0.580			
A-No[g]	1058			0.413	0.596			
B-Yes[h]	163			0.398	0.463	A-B	0.03	Trivial

a : Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Nonsignificant (NS); d : Standard deviation ; e: Comparison; f :Effect size obtained by dividing the difference between the two groups by the total standard deviation g : No : Groups of students who did not study SAS biology n 1995; h : Yes: Groups of students who did study SAS biology in 1995; i: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Appendix 8.2a Courses for further education - views on Society Scale

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[n]
Society	1197	2.83	S	0.216	0.586			
A-Agriculture[g]	59			0.214	0.721	B-A	0.36	Small
B-Applied science[h]	87			0.426	0.492	B-C	0.43	Small
C-Architecture[i]	42			0.174	0.845	B-D	0.48	Small
D-Art, design, music	122			0.142	0.504	B-E	0.41	Small
E-Business & commercial stud.	199			0.184	0.611	B-F	0.35	Small
F-Education[j]	100			0.221	0.632	B-H	0.32	Small
G-Engineering & technology	121			0.299	0.489	B-J	0.76	Medium
H-General studies[k]	188			0.236	0.580	G-A	0.15	Trivial
I-Health sciences[l]	130			0.369	0.447	G-B	0.21	Small
J-Don't expect[m]	149			-0.018	0.589	G-D	0.27	Small
						G-C	0.21	Small
						G-J	0.54	Medium
						I-A	0.27	Small
						I-C	0.27	Small
						I-D	0.38	Small
						I-F	0.25	Small
						I-H	0.23	Small
						I-J	0.66	Medium

a : Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c : Significant (S) or Non significant (NS); d : Standard deviation; e : Comparison; f :Effect size obtained by dividing the difference between the two groups by the total standard deviation; g : Agriculture, fishing, forestry; h : Science, applied science, mathematics; i : Architecture, building, surveying; j :Education, including teacher training; k : General studies and social sciences, including history, law, religious studies, psychology and sociology; l: Health sciences, including nursing and medicine; m : Expect not to continue education after school; n: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Appendix 8.2b Courses for further education - views on Science Scale

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[n]
Science	1197	3.36	S	0.321	0.547			
A-Agriculture[g]	59			0.294	0.592	B-A	0.27	Small
B-Applied science[h]	87			0.442	0.356	B-C	0.35	Small
C-Architecture[i]	42			0.251	0.800	B-D	0.21	Small
D-Art, design, music	122			0.326	0.502	B-E	0.35	Small
E-Business & commercial stud.	199			0.253	0.538	B-F	0.20	Small
F-Education[j]	100			0.329	0.489	B-H	0.11	Trivial
G-Engineering & technology	121			0.413	0.560	B-J	0.68	Medium
H-General studies[k]	188			0.380	0.567	G-A	0.22	Small
I-Health sciences[l]	130			0.489	0.439	G-B	0.05	Trivial
J-Don't expect[m]	149			0.068	0.575	G-C	0.30	Small
						G-D	0.16	Trivial
						G-J	o.63	Medium
						I-A	0.35	Small
						I-C	0.43	Small
						I-D	0.30	Small
						I-F	0.29	Small
						I-H	0.20	Trivial
						I-J	0.70	Medium

a : Number, b: Adjusted F ratio - F ratio/2 due to clustering (general); c : Significant (S) or Non significant (NS); d : Standard deviation; e : Comparison; f :Effect size obtained by dividing the difference between the two groups by the total standard deviation; g : Agriculture, fishing, forestry; h : Science, applied science, mathematics; i : Architecture, building, surveying; j :Education, including teacher training; k : General studies and social sciences, including history, law, religious studies, psychology and sociology; l: Health sciences, including nursing and medicine; m: Expect not to continue education after school; n: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Appendix 8.2c Courses for further education - views on Scientists Scale

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[n]
Scientist	1197	4.86	S	0.409	0.587			
A-Agriculture[g]	59			0.309	0.663	B-A	0.37	Small
B-Applied science[h]	87			0.523	0.499	B-C	0.45	Small
C-Architecture[i]	42			0.260	0.799	B-D	0.20	Small
D-Art, design, music	122			0.405	0.540	B-E	0.35	Small
E-Business & commercial stud.	199			0.314	0.545	B-F	0.19	Trivial
F-Education[j]	100			0.411	0.453	B-G	0.11	Trivial
G-Engineering & technology	121			0.458	0.583	B-H	0.03	Trivial
H-General studies[k]	188			0.507	0.625	B-J	0.66	Medium
I-Health sciences[l]	130			0.695	0.557	G-A	0.25	Small
J-Don't expect[m]	149			0.136	0.540	G-A	0.25	Small
						G-C	0.34	Small
						G-D	0.09	Trivial
						G-J	0.55	Medium
						I-A	0.66	Medium
						I-C	0.74	Medium
						I-D	0.49	Small
						I-F	0.48	Small
						I-H	0.32	Small
						I-J	0.95	Large

a : Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c : Significant (S) or Non significant (NS); d : Standard deviation; e : Comparison; f :Effect size obtained by dividing the difference between the two groups by the total standard deviation; g : Agriculture, fishing, forestry; h : Science, applied science, mathematics; i : Architecture, building, surveying; j :Education, including teacher training; k : General studies and social sciences, including history, law, religious studies, psychology and sociology; l: Health sciences, including nursing and medicine; m : Expect not to continue education after school; n: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Appendix 8.3a Occupation after school - views on Society Scale

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[n]
Society	1180	2.99	S	0.221	0.588			
A-Professional	585			0.302	0.558	A-E	0.22	Small
B-Managerial	51			0.214	0.719	A-G	0.30	Small
C-Clerical & related workers	214			0.225	0.581	A-F	0.43	Small
D-Skilled workers[g]	70			0.023	0.655	A-B	0.15	Trivial
E-Semiskilled workers[h]	22			0.171	0.553	B-E	0.07	Trivial
F-Unskilled workers[i]	84			0.048	0.608	B-F	0.28	Small
G-Other	154			0.124	0.567	B-G	0.15	Trivial
						C-D	0.42	Small
						C-E	0.09	Trivial
						C-G	0.17	Trivial
						D-E	0.33	Small
						D-F	0.12	Trivial
						D-G	0.25	Small

a : Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c : Significant (S) or Non significant (NS); d : Standard deviation; e : Comparison; f :Effect size obtained by dividing the difference between the two groups by the total standard deviation; g : Craftsmen and foremen-skilled occupation; h : Shop assistants, operative and process workers, drivers -semiskilled occupation; i : Domestic, personal and other service workers-unskilled occupation; n : For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Appendix 8.3b Occupation after school - views on Science Scale

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[n]
Science	1180	5.23	S	0.323	0.548			
A-Professional	585			0.439	0.537	A-E	0.20	Trivial
B-Managerial	51			0.295	0.682	A-G	0.46	Medium
C-Clerical & related workers	214			0.253	0.452	A-F	0.58	Medium
D-Skilled workers[g]	70			0.126	0.507	A-B	0.26	Small
E-Semiskilled workers[h]	22			0.330	0.479	B-E	0.06	Trivial
F-Unskilled workers[i]	84			0.122	0.611	B-F	0.31	Small
G-Other	154			0.186	0.558	B-G	0.11	Trivial
						C-G	0.06	Trivial
						C-E	0.14	Trivial
						C-D	0.23	Small
						E-D	0.37	Small
						D-F	0.01	Trivial
						G-D	0.11	Trivial

a : Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c : Significant (S) or Non significant (NS); d : Standard deviation; e : Comparison; f :Effect size obtained by dividing the difference between the two groups by the total standard deviation; g : Craftsmen and foremen-skilled occupation; h : Shop assistants, operative and process workers, drivers -semiskilled occupation; i : Domestic, personal and other service workers-unskilled occupation; n : For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Appendix 8.3c Occupation after school - views on Scientists Scale

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[n]
Scientist	1180	4.84	S	0.416	0.585			
A-Professional	585			0.536	0.603	A-E	0.23	Small
B-Managerial	51			0.243	0.578	A-G	0.40	Small
C-Clerical & related workers	214			0.344	0.481	A-F	0.45	Small
D-Skilled workers[g]	70			0.155	0.538	A-B	0.50	Medium
E-Semiskilled workers[h]	22			0.403	0.631	A-C	0.33	Small
F-Unskilled workers[i]	84			0.270	0.498	A-D	0.65	Medium
G-Other	154			0.319	0.614	B-E	0.32	Small
						B-F	0.04	Trivial
						B-G	0.13	Trivial
						C-G	0.04	Trivial
						C-E	0.10	Trivial
						C-D	0.32	Small
						D-E	0.42	Small
						D-F	0.20	Trivial
						D-G	0.28	Small

a : Number b: Adjusted F ratio - F ratio/2 due to clustering (general); c : Significant (S) or Non significant (NS); d : Standard deviation; e : Comparison; f :Effect size obtained by dividing the difference between the two groups by the total standard deviation; g : Craftsmen and foremen-skilled occupation; h : Shop assistants, operative and process workers, drivers - semiskilled occupation; i : Domestic, personal and other service workers-unskilled occupation; n : For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Appendix 8.4a Father's occupation - views on Society Scales

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[x]
Society	1154	0.93	NS	0.222	0.594			
A-Professional	267			0.287	0.526	A-E	0.30	Small
B-Managerial	166			0.223	0.723	A-G	0.23	Small
C-Clerical and related workers	163			0.244	0.515	A-F	0.10	Trivial
D-Skilled workers[g]	149			0.264	0.453	A-B	0.10	Trivial
E-Semiskilled workers[h]	101			0.106	0.678	D-E	0.27	Small
F-Unskilled workers[i]	91			0.225	0.656	D-G	0.19	Trivial
G-Other	217			0.151	0.627	D-F	0.06	Trivial
						B-E	0.19	Trivial
						B-G	0.12	Trivial
						C-G	0.16	Trivial
						C-E	0.23	Small
						C-D	0.03	Trivial
						F-B	0.01	Trivial
						F-G	0.13	Trivial
						F-E	0.20	Small

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Nonsignificant (NS); d: Standard deviation; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the total standard deviation; g: Craftsmen and foremen-skilled occupation; h: Shop assistants, operative and process workers, drivers -semiskilled occupation; i: Domestic, personal and other service workers-unskilled occupation; x: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Appendix 8.4b Father's occupation - views on Science Scale

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[x]
Science	1154	1.70	NS	0.330	0.551			
A-Professional	267			0.408	0.515	A-E	0.34	Small
B-Managerial	166			0.358	0.655	A-G	0.29	Small
C-Clerical & related workers	163			0.390	0.497	A-F	0.29	Small
D-Skilled workers[g]	149			0.353	0.425	A-B	0.09	Trivial
E-Semiskilled workers[h]	101			0.219	0.573	D-E	0.24	Small
F-Unskilled workers[i]	91			0.250	0.597	D-G	0.21	Small
G-Other	217			0.237	0.575	D-F	0.18	Trivial
						B-E	0.25	Small
						B-F	0.25	Small
						B-G	0.22	Small
						C-G	0.28	Small
						C-E	0.30	Small
						C-D	0.07	Trivial
						F-G	0.02	Trivial
						F-E	0.06	Trivial

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Nonsignificant (NS); d: Standard deviation; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the total standard deviation; g: Craftsmen and foremen-skilled occupation; h: Shop assistants, operative and process workers, drivers -semiskilled occupation; i: Domestic, personal and other service workers-unskilled occupation; x: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Appendix 8.4c Father's occupation - views on Scientists Scale

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[x]
Scientist	1154	1.66	NS	0.419	0.590			
A-Professional	267			0.521	0.586	A-E	0.19	Trivial
B-Managerial	166			0.437	0.707	A-G	0.35	Small
C-Clerical & related workers	163			0.405	0.500	A-F	0.38	Small
D-Skilled workers[g]	149			0.460	0.570	A-B	0.14	Trivial
E-Semiskilled workers[h]	101			0.410	0.611	D-E	0.08	Trivial
F-Unskilled workers[i]	91			0.299	0.573	D-G	0.25	Small
G-Other	217			0.314	0.553	D-F	0.27	Small
						B-E	0.04	Trivial
						B-F	0.23	Small
						B-G	0.20	Small
						C-G	0.15	Trivial
						C-E	0.01	Trivial
						D-C	0.09	Trivial
						F-E	0.19	Trivial
						G-F	0.03	Trivial

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Nonsignificant (NS); d: Standard deviation; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the total standard deviation; g: Craftsmen and foremen-skilled occupation; h: Shop assistants, operative and process workers, drivers -semiskilled occupation; i: Domestic, personal and other service workers-unskilled occupation; x: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Appendix 8.5a Mother's occupation - views on Society Scale

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[x]
Society	1150	1.13	NS	0.225	0.593			
A-Professional	188			0.285	0.478	A-E	0.15	Trivial
B-Managerial	125			0.331	0.516	A-G	0.21	Small
C-Clerical & related workers	175			0.191	0.749	A-F	0.01	Trivial
D-Skilled workers[g]	91			0.270	0.457	B-A	0.08	Trivial
E-Semiskilled workers[h]	65			0.199	0.464	B-E	0.22	Small
F-Unskilled workers[i]	109			0.280	0.664	B-F	0.09	Trivial
G-Other	397			0.156	0.607	B-G	0.30	Small
						C-G	0.06	Trivial
						D-C	0.13	Trivial
						D-E	0.12	Trivial
						D-G	0.21	Small
						E-C	0.01	Trivial
						F-D	0.02	Trivial
						F-G	0.21	Small
						F-E	0.14	Trivial

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Nonsignificant (NS); d: Standard deviation; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the total standard deviation; g: Craftsmen and foremen-skilled occupation; h: Shop assistants, operative and process workers, drivers -semiskilled occupation; i: Domestic, personal and other service workers-unskilled occupation; x: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Appendix 8.5b Mother's occupation - views on Science Scale

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[x]
Science	1150	1.59	NS	0.331	0.552			
A-Professional	188			0.394	0.470	A-E	0.25	Small
B-Managerial	125			0.451	0.476	A-G	0.30	Small
C-Clerical & related workers	175			0.332	0.708	A-F	0.14	Trivial
D-Skilled workers[g]	91			0.412	0.445	B-A	0.10	Trivial
E-Semiskilled workers[h]	65			0.259	0.453	B-E	0.35	Small
F-Unskilled workers[i]	109			0.328	0.620	B-F	0.22	Small
G-Other	397			0.256	0.539	B-G	0.35	Small
						C-E	0.13	Trivial
						C-G	0.14	Trivial
						D-C	0.15	Trivial
						D-E	0.28	Small
						D-F	0.15	Trivial
						D-G	0.28	Small
						F-E	0.13	Trivial
						F-G	0.13	Trivial

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Nonsignificant (NS); d: Standard deviation; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the total standard deviation; g: Craftsmen and foremen-skilled occupation; h: Shop assistants, operative and process workers, drivers -semiskilled occupation; i: Domestic, personal and other service workers-unskilled occupation; x: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Appendix 8.5c Mother's occupation - views on Scientists Scale

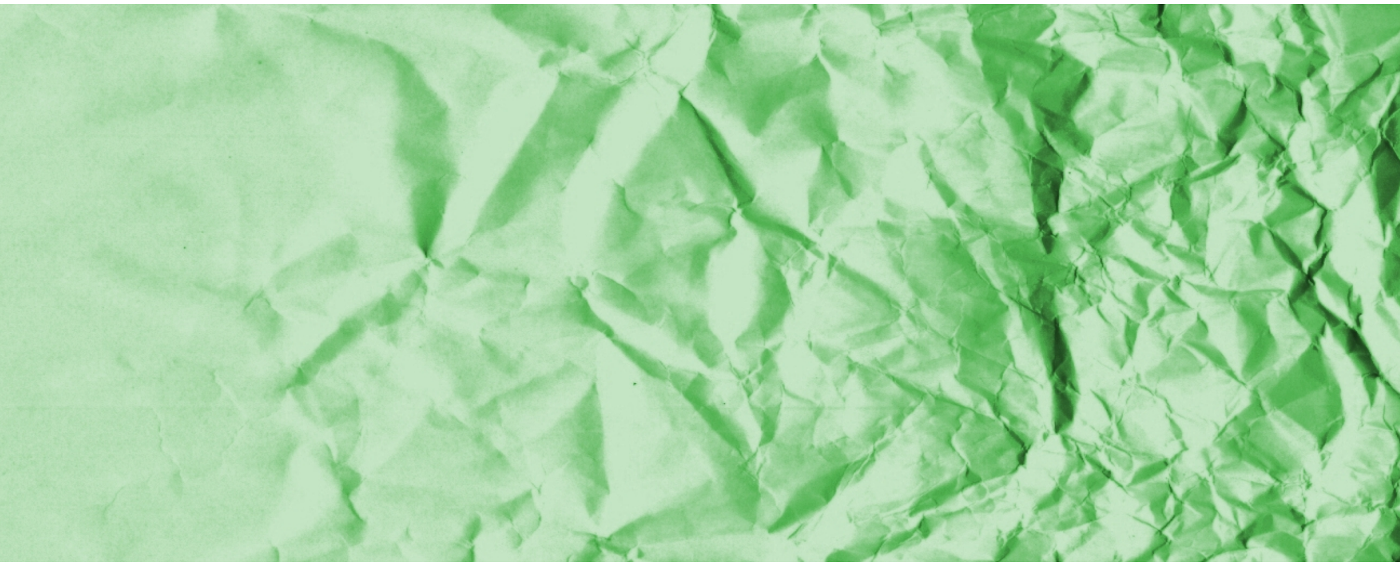
Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[x]
Scientist	1150	1.04	NS	0.419	0.591			
A-Professional	188			0.454	0.572	A-E	0.00	Trivial
B-Managerial	125			0.518	0.500	A-G	0.18	Trivial
C-Clerical & related workers	175			0.395	0.635	A-F	0.00	Trivial
D-Skilled workers[g]	91			0.498	0.510	B-A	0.11	Trivial
E-Semiskilled workers[h]	65			0.453	0.590	B-E	0.100	Trivial
F-Unskilled workers[i]	109			0.453	0.668	B-F	0.11	Trivial
G-Other	397			0.348	0.596	B-G	0.29	Small
						C-G	0.08	Trivial
						D-C	0.17	Trivial
						D-E	0.08	Trivial
						D-F	0.08	Trivial
						D-G	0.25	Small
						E-C	0.10	Trivial
						F-E	0.00	Trivial
						F-G	0.18	Trivial

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Nonsignificant (NS); d: Standard deviation; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the total standard deviation; g: Craftsmen and foremen-skilled occupation; h: Shop assistants, operative and process workers, drivers -semiskilled occupation; i: Domestic, personal and other service workers-unskilled occupation; x: For effect size classification see Chapter 5 and Cohen (1969, p. 25).

Appendix 8.6 Location - views on Society, Science and Scientists Scales

Group	N[a]	Fb ratio	S or NS[c]	Mean	SD[d]	Com[e]	Effect Size[f]	Effect Size Category[i]
Society	1278	0.25	NS	0.210	0.590			
A-Metrop[g]	1038			0.216	0.590			
B-Non-met[h]	240			0.186	0.592	A-B	0.05	Trivial
Science	1278	1.54	NS	0.317	0.548			
A-Metrop[g]	1038			0.330	0.554			
B-Non-met[h]	240			0.261	0.518	A-B	0.13	Trivial
Scientists	1278	0.11	NS	0.408	0.582			
A-Metrop[g]	1038			0.411	0.588			
B-Non-met[h]	240			0.392	0.558	A-B	0.03	Trivial

a: Number; b: Adjusted F ratio - F ratio/2 due to clustering (general); c: Significant (S) or Nonsignificant (NS); d: Standard deviation ; e: Comparison; f: Effect size obtained by dividing the difference between the two groups by the total standard deviation; g: Metropolitan schools; h: Non-metropolitan schools; i: For effect size classification see Chapter 5 and Cohen (1969, p. 25).



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