CHAPTER ONE

AN OVERVIEW OF THE STUDY

INTRODUCTION

In an address to the National Press Club in 1998, the president of the Australian Vice Chancellors Committee, Professor John Niland, argued that Australia, and New South Wales (NSW) in particular, were suffering from 'a declining interest by bright students' in the further study of science (Niland 1998, p. 3). Although his address primarily concerned the challenges confronting university science, Professor Niland made the point that this decline can be traced back to high schools, where, over the last decade or so, decreasing proportions of students have been choosing university prerequisite science subjects in their senior years (Dekkers & DeLaeter 1997; Niland 1998). The importance of investigating the enrolment decisions of high achieving students was earlier recognised by the Science and Technology Working Party of the National Board of Employment, Education and Training (NBEET), which called for studies that could provide insights into the experiences and intentions of such students regarding further science study (NBEET 1993, p. 34). The present study is the first in Australia to expressly focus on the contrasting senior science enrolment decisions of high achieving, or science proficient, junior high school students.

Three years prior to Professor Niland's address, the results were published of a Californian study concerned with the 'differential experiences' of high school science students, including two groups of high achieving students (Costa 1995). Costa described a model in which aspects of students' engagement with school science could be understood in terms of their negotiations of the different characteristics of their family, school and peer 'worlds'. In particular, Costa argued that the differential experiences of the high achieving students in her study were influenced by the levels of congruence between their experiences of school science, and the sociocultural characteristics of their personal worlds. The wider implications of the model used by Costa were recognised by Aikenhead (1996, 1998, 2001), who subsequently expanded its theoretical base and encouraged science education researchers to investigate its applicability to other contexts.

The study described herein was conducted in response to the imperatives outlined above. As such, it is situated at the intersection of three areas of research interest: the persistent declines in NSW school science participation; the experiences and enrolment decisions of high achieving science students; and the complex sociocultural influences on students' educational outcomes. Since decision making about future engagement with science was central to the research, the study focused on 'science proficient' students in NSW at a critical decision point in their lives - the subject selection process in Year 10.

THE CONTEXT OF SENIOR SCIENCE ENROLMENT IN NSW SCHOOLS

The overall structure of high school science education in NSW is similar to that found in many western countries. The first four years of high school (Years 7 to 10) are compulsory, with students taking an integrated science course. Most Year 10 students (15 - 16 year olds) continue to post-compulsory high school education (Years 11 and 12), choosing their senior courses from a number of Key Learning Areas (KLAs), including science. However, science courses are not compulsory in Years 11 and 12; indeed, the only compulsory course is English. Throughout the senior years, achievement in different courses is assessed both internally and externally, contributing to a Higher School Certificate (HSC) mark for each course.

When the data for this study were collected in 1998, the NSW Board of Studies offered a number of specialist and non-specialist HSC science courses, in a range of configurations differentiated by 'units'. The number of units allocated for a course corresponded to the amount of indicative school time spent studying that course (Board of Studies [BoS] 2000). The four specialist subjects: physics, chemistry, biology and geology, were available as 2 unit courses. The non-specialist, or integrated, science courses included 4 unit Science, 3 unit Science, 2 unit Science for Life and 2 unit General Science. A few schools also offered content endorsed courses such as Marine Studies, though these were assessed by the individual school rather than through public examination. Since all but one of the science subjects discussed in this study were available only as 2 unit courses, the terms *subject* and *course* are used interchangeably in this thesis. The exception was 3 unit science, which is referred to as a course.

In general, the HSC science subjects most commonly undertaken by students are physics, chemistry and biology. These subjects, together with the less frequently chosen Science for Life and General Science courses, account for about 97 per cent of senior science enrolments (Barnes 1999). Physics and chemistry, in particular, are often prerequisites or assumed knowledge for university courses in medicine, health, engineering, science and science teaching. As well as the requirement to have completed particular subjects, entrance to many university courses is dependent upon a student's Universities Admission Index (UAI) ranking. This ranking indicates a student's achievement in relation to other students, based upon an aggregate of scaled marks in courses completed for the HSC (BoS 1998a, 2000). In practical terms, the higher a student's UAI ranking, the more university options they have.

The increasing tendency for high school students to forgo the further study of science appears to be symptomatic of a more general malaise afflicting Australian science education. In addition to declines in enrolment in the traditional senior science subjects (Ainley, Robinson, Harvey-Beavis, Elsworth & Fleming 1994; Dekkers & De Laeter 1997, 2001; Fullarton & Ainley 2000), there continues to be concern over key indicators such as enrolments in many tertiary science courses (Australian Council of Deans of Science [ACDS] 1999; Niland 1998), the uptake of science careers (Australian Academy of Science [AAS] 1993; ACDS 1999; Australian Science and Technology Council [ASTEC] 1991; Goodrum, Hackling & Rennie 2001; NBEET 1994; Ridd & Heron 1998) and the general standard of scientific literacy of present and future generations (Galbraith, Carss, Grice, Endean & Warry 1997; Rosier & Banks 1990).

The indicator of most immediate concern to secondary science teachers is that of participation rates in the main public examination science courses: physics, chemistry and biology (Goodrum et al. 2001; Werry 1998). While Dekkers and DeLaeter (1997, 2001) have reported significant decreases in enrolments in these courses since 1992, when compared to overall Year 12 populations, declining participation rates in science have been a feature of the educational landscape since 1980 (Dekkers & DeLaeter 2001). Similar trends have been observed in other countries, including the USA (Olsen 1998; Tobias 1990), the UK (Bennett 2001; Osborne, Driver & Simon 1998; Ramsden 1998), Germany (Paul, Völl & Jäger 2001) and Norway (Sjøberg 2000).

In NSW the trend has been more pronounced than elsewhere in Australia, with this state often recording the lowest Year 12 science participation rates of all states and territories (Ainley et al. 1994; Fullarton & Ainley 2000). Coupled with these data is the lower priority given to school science by NSW students, who generally see it as being less personally relevant than do students elsewhere in Australia (Rosier & Banks 1990).

The issues outlined above have prompted a number of Australian researchers to investigate the factors associated with science enrolment (e.g. Ainley 1993; Barnes 1999). In order to complement these quantitative studies, and provide some interpretation of the statistical associations they revealed, an alternative approach, such as that advocated by Costa (1995) and Aikenhead (1996) is required.

THE FOCUS OF THE STUDY

The research imperatives mentioned in the introduction provided this study with its focus and approach. The initial reasons for investigating the experiences and deliberations of science proficient students have already been outlined. In addition, however, there was the recognition that participation in some high school science courses has been associated with levels of earlier academic achievement (Ainley et al. 1994). The issue of enrolment decisions becomes more intriguing when the study population is restricted to students who have already demonstrated the potential to successfully undertake senior science courses. In largely eliminating the question of academic ability in science, this research was able to look for alternative influences.

In the context of this study, being ‘proficient’ in school science was interpreted as being ‘highly competent’ (Krebs 1981; Neufeldt & Guralnik 1988) or ‘expert’ (Simpson & Weiner 1989) in the subject, rather than implying merely capable, as is sometimes the vernacular interpretation. At the time this study was conducted, assessment of a student’s overall achievement in school science in Year 10 was determined by their teachers, with reference to an externally prescribed set of performance descriptors (see Appendix A). Students were awarded a School Certificate grade in science, from ‘A’ to ‘E’, according to their performance in a series of formal assessment tasks, as measured against the descriptors for each grade. For the purpose of this study, students who had been awarded an 'A', which recognised 'excellent achievement' in science, or a 'B', which corresponded to 'high achievement', were regarded as being science proficient (BoS 1998b). Conventionally, these grades had been awarded to the top 30 per cent of Year 10 students statewide[1]. This grading system was considered a valid way of determining proficiency in science, since it did not depend on the outcome of a single examination, but rather on the longitudinal performance of each student. Furthermore, the use of external performance descriptors in assigning grades to students was designed to ensure a measure of comparability in the grades awarded by different schools (BoS 1998b).

The process of choosing senior subjects, which generally occurs early in the second semester of Year 10, can be difficult for many students (Mitchell 1997). They are required to weigh competing imperatives, to anticipate the consequences of their decisions and to contend with the limitations of school timetable structures. They also need to consider HSC regulations and, in many cases, university requirements. The decisions made in Year 10 are critical in terms of a student's future relationship with science, since a decision to forgo senior science courses generally makes future engagement with science, at least in a formal sense, difficult. In addition, decisions to forgo science may mean that personal levels of scientific literacy do not progress far beyond junior high school levels. This has serious implications with respect to the abilities of 21st century Australians to understand and debate social issues involving science and technology (Galbraith et al. 1997; Rosier & Banks 1990).

Curiosity about the enrolment decisions of science proficient students was stimulated by Costa's (1995) finding that cultural differences between home, peer and school worlds affected the ways in which high achieving science students perceived their experiences of school science. Although Costa's study did not focus exclusively on high achieving students, this particular finding, and the border crossing dynamic used to explain it, nevertheless provided a formative theoretical model for the present study. While the influence of culture on science education outcomes has been examined from a number of perspectives (e.g. Baker & Taylor 1995; Jegede 1994; Maddock 1981; Ogawa 1995; Ogunniyi 1988), these studies have, in the main, considered cultural differences in terms of different ethnic identities. Costa's argument, like that of Phelan, Davidson and Cao (1991) whose work informed her study, was that even among students who shared the dominant culture, congruency or incongruency between the culture of school science and family or peer cultures were often substantial enough to affect students' engagement with science.

The contribution of Costa's work, and that of Phelan et al. (1991), was recognised by Aikenhead (1996, 1998, 2001) who referred extensively to these studies in calling for a cultural perspective of science education which 'addresses science education for *Western*

[1] In terms of School Certificate assessment, 1998 was a transition year. The Year 10 Reference Test in Science, previously conducted in July/August each year, was temporarily discontinued. Results from this test had been used to guide teachers in the awarding of grades. In 1998, schools awarded grades (A-E), using *only* the Course Performance Descriptors. In 1999, tests were again compulsory for all School Certificate science students (BoS 1998b).

students in *industrialised* countries' (1996, p. 2, his emphasis). Aikenhead proposed that researchers consider students' experiences in a science classroom in terms of border crossing, from the worlds of their peers and family into that of school science. He also maintained that a model which considers the dynamics of border crossing could provide science educators with a 'new vantage point from which to analyze familiar problems' (1996, p. 2). One of the familiar problems in NSW education is that of declining participation in senior science courses, and this study accepted Aikenhead's challenge to utilise Costa's framework in examining this issue.

Thematic Research Questions

The holistic and interactive nature of the theoretical model encouraged exploration both within and between students' sociocultural worlds, for influences on their science enrolment decisions. The exploration within each world was guided by the following thematic research question:

> What are the influences on science proficient students' decisions about enrolling in senior high school science courses?

However, the study was particularly interested in whether students' negotiations of the characteristics within different worlds influenced their enrolment decisions. Therefore, a second thematic question was proposed:

> Does cultural congruence or incongruence between the different worlds of science proficient students play a part in their science enrolment decisions?

These thematic questions gave rise to a number of more specific questions, detailed in Chapter Two.

Overview of the Research Design

To explore the research questions, the study employed three strategies, in a two stage approach. The first stage began with a survey of 196 science proficient students, from six schools, regarding their background details, senior subject choices and influential sources of advice. Another preliminary survey sought the perceptions of 24 science teachers from the six schools concerning enrolment trends in their schools, and the enrolment decisions of science proficient students in particular. Findings from these two surveys informed the second, and most substantial, stage of the study. This involved individual interviews with 37 of the surveyed students who had made decisions for and against enrolment in senior science courses. The in-depth interviews, which explored students' perceptions of influences within their family, peer, school science and mass media worlds, constituted the principal focus of the study.

THE SIGNIFICANCE OF THE STUDY

The conclusions of the study have significance for both the research endeavour and for practitioners of science education. In terms of theory, the study is important as it is the first in Australia to explore in detail, from the perspectives of science proficient students, those sociocultural factors which statistical studies, introduced in the next chapter, have shown to be associated with science enrolment decisions. The interpretive approach allowed aspects of cause and effect, which cannot be assumed in factorial studies, to emerge from the data. The research is also significant in being the first to apply the framework developed by Phelan et al. (1991) and Costa (1995) to a contextual problem in Australia. Thus, the study explored new territory not only in terms of its population focus, but also with regard to the application of new theory.

In terms of practical value to science educators, the study identified a number of attributes and conditions influential in the enrolment decisions of science proficient students. While some of these influences were found outside the world of school science, others were characteristics of the culture of school science, as it is commonly experienced in NSW. Thus, the conclusions of the study have considerable relevance to science teachers. Furthermore, the fact that this research focused on the perceptions of science proficient students should be of particular interest to teachers, given the opinion expressed in some quarters that academic ability is a dominating factor in declining enrolments in the 'hard sciences' (Werry 1998; Woolnough 1993).

Finally, the study argues that the use of narratives to illustrate students' perceptions and deliberations may help teachers, parents and curriculum designers understand more about the young people who come into science classrooms, and the heterogeneity of their cultural environments. A perspective showing school science to be just one of the worlds students are expected to traverse may influence some educators to move away from a science-centric view towards a student-centric one. In exploring the perceptions of science proficient students who have decided to continue with, or to forgo, further science education, the present study provides a different perspective on declining participation in senior secondary science education. It is also hoped that the depth of this investigation may cast some light on the dynamic role of culture in influencing students' decisions about engaging in further science study.

THE RESEARCH BOUNDARIES

The definitions of some key concepts, such as *culture*, *multiple worlds* and *school science*, involve extensive reference to the literature, and are therefore discussed in greater detail in the next chapter. However, some indication of the scope, perspective and boundaries of the study is provided below.

Delimitations

In terms of its approach, the study was a sociocultural exploration using a theoretical model appropriated from educational anthropology. Thus, much of the language and methodology of the thesis is drawn from the interpretive paradigm. The term *sociocultural* has been used in the literature to describe a range of perspectives (e.g. Fishman 1972; Hansen 1979; Tiryaken 1963; Vygotsky 1978). This study subscribed to the interpretation used by Maehr and Stallings (1975), who regarded a person's sociocultural background as a social matrix for development and behaviour which recognises the influence of culture as a shared orientation (1975, p. 2). It is argued in Chapter Two that the strong associations found by previous studies between students' enrolment decisions and social and cultural factors, indicate that taking a sociocultural approach had a greater potential to help researchers understand these decisions than did cognitive or other approaches.

With regard to the study population, the conclusions of this study were intended to apply only to science proficient students in NSW who were progressing from Year 10 to senior high school in 1998. The degree to which the conclusions are applicable to other populations or contexts is dependent upon their similarity with those of the study. This issue of transferability is discussed in Chapter Three.

It should also be noted that within the student population, not all categories of science subject choice have been represented. The study divided students into three choice categories: those choosing predominantly physical science subjects; those taking mainly biological or other science; and those choosing no science at all. The decision to focus on these choice categories was based upon the findings of previous studies, as outlined in the next chapter. However, while these categories accommodated the vast majority of the study population, this artificial distinction meant that the views of the few students who did not fit into these classifications were not represented in this study.

Finally, apart from the opinions of science teachers, the data were limited to the perceptions of students. The subjectivity of the data therefore had important methodological implications, discussed in detail in Chapter Three. Briefly, however, the decision to focus on students' perceptions recognised that a person's motivations can best be understood by sharing their frame of reference (Kvale 1996; Taylor & Bogdan 1998). Thus, it should be understood that the data were not meant to constitute an objective 'reality', but rather to represent the students' interpretations of reality.

Limitations

All field research is essentially a compromise between the ideal and the practical (Sowden & Keeves 1988). In terms of research integrity, the 'ideal' study would have involved larger populations and follow-up interviews to confirm or refute emerging theory. In practical terms, however, the most constraining limitation on the scale of this study was the small time window available for data collection. Because of the particular context of the study, it was not possible to identify the population of science proficient students, or even the pilot samples, until the schools had allocated their School Certificate science grades, and the students had confirmed their Year 11 subject choices. In most cases this left a period of less than eight weeks for data collection before the end of the school year. Access to students during this period was further reduced by examinations and end of year excursions.

The size of the study populations was also restricted by the complexity of coordinating the three data collection strategies, needed to provide methodological and data triangulation. Since the interview schedule was informed by analyses of data from the preliminary studies, there was necessarily a delay between the data collection phases. The consideration of time as an element of the population (LeCompte & Preissle 1993) thus placed practical restrictions on the size of the interview cohort and the number of participating schools. The fact that the schools were selected from different locations across the state, and were in some cases over 700 km apart, contributed to the practical difficulties.

Despite the restrictions of time and distance, the original inclusion of seven schools, and the anticipated study population of about 220 students, were considered more than adequate to provide a credible representation of science proficient students in New South Wales. However, as explained in Chapter Three, one of the designated schools was forced to withdraw from the study at a stage when it was too late to include the back-up school. While this withdrawal was not considered to have impacted substantially on the overall conclusions, the inclusion of this school, given the demographic characteristics of its population, would have enhanced the credibility of the study.

Another limitation was the wide scope of the study, requiring the exploration of students' family, peer, school science and mass media worlds for indications of influence on students' subject choices. Each one of these worlds proved to be extensive and complex enough to justify a study in its own right. In some cases, the interviews revealed rich and intriguing responses that could not be adequately explored without neglecting other interview foci. Nevertheless, the breadth of the exploration was also one of its strengths, and a necessary consequence of the holistic approach prescribed by the theoretical model. While the issues discussed above represented the main limitations of the study, other compromises and possible methodological restrictions are outlined in Chapter Three.

THE STRUCTURE OF THE THESIS

The next chapter begins by discussing in greater detail the decline in high school science enrolments in NSW, and in Australia more generally, as well as the short and long term implications of these declines. A conceptual framework is then constructed with reference to significant studies which have previously sought to identify the factors associated with students' science enrolment decisions. Following a critique of these studies, the chapter describes the sociocultural research which provided the theoretical model and methodological considerations guiding the present study.

Chapter Three expands upon these considerations, describing in detail the methodologies used to identify the study populations and to reveal and analyse students' and teachers' perceptions of the influences on science enrolment decisions. The chapter also discusses issues of research integrity, including the trustworthiness of the conclusions.

Chapters Four to Seven present and discuss the results of the study. The analyses reported in Chapter Four concern the 'topographical' features of science enrolment decisions. These were the patterns most readily apparent within biographical profiles, science course choices and students' rationales for their decisions. The views of science teachers are also examined in this chapter and compared with the explanations given by science proficient students for their enrolment decisions. Patterns within these data are explored, with particular reference to the significant others whom students perceived to have influenced their deliberations. Chapters Five, Six and Seven address students' perceptions of their school science, peer, mass media and family worlds. In these chapters, portraits of the structural, attitudinal and dynamic dimensions of each world are composed, identifying the cultural influences on students' decisions.

Chapter Eight summarises the conclusions drawn from the study with reference to the research foci. The implications of these conclusions for theory, practice and further research are also discussed.

CHAPTER TWO

HIGH SCHOOL SCIENCE ENROLMENT DECISIONS: FRAMEWORKS FOR EXPLORATION

INTRODUCTION

Recent newspaper headlines, such as 'Sciences face academic extinction' (Contractor 2002), 'Physics faces chop as students shun sciences' (Chynoweth 2001), and 'Students desert hard sciences' (Australian, 10th June 1998) are indicative of the degree to which concerns about school science enrolment rates have become part of the public consciousness. Yet, despite the implications of immediacy in these headlines, decreasing participation rates in science courses have been a feature of Australian high school enrolment profiles for over two decades.

The literature concerning this problem covers a range of issues including speculation about causes, investigation of students' motivations, implications of these trends for science and science education and suggestions for measures which might stem or perhaps even reverse the declines. Within the literature are a number of important Australian and international studies that have contributed significantly to the conceptual framework guiding the present study.

For the purposes of this review, these studies are considered as relating to three research themes, discussed in this chapter. The first concerns the documentation of enrolment trends in senior physics, chemistry and biology courses, both nationally and in NSW. Falling enrolments in NSW are of particular interest due to other concerns about NSW students' responses to school science more generally. These concerns have crucial implications for students and for Australian society in the longer term.

A second theme addresses the process of science subject choice in NSW high schools, and the issues identified in the literature as being influential in students' enrolment decisions. In acknowledging the important contributions of these quantitative studies to an understanding of the factors associated with particular choices, it is also recognised that there has long been a need to complement such research with alternative approaches.

The third theme concerns one such approach. As noted in Chapter One, the sociocultural model developed by Phelan, Davidson and Cao (1991) and Costa (1995) provided a new conceptualisation of students' interactions with science, and a novel framework within which influences and dynamics may be situated and explored. The evaluation and modification of this model, with reference to a range of literature, led to construction of the framework used in addressing the research questions, developed in greater detail at the end of this chapter.

HIGH SCHOOL SCIENCE ENROLMENTS TRENDS

Studies of student enrolments in senior high school science courses in Australia since 1980 have documented decreasing rates of participation in proportion to the total Year 12 cohort (Dekkers & De Laeter 1997, 2001). The level of disquiet among science educators over the extent of this decline was recognised by Dekkers and DeLaeter (1997, p. 36) who spoke of 'an Australia wide concern' with respect to the low levels of student participation in senior high school science courses, 'particularly those leading to further education and careers in science and mathematics.' The declines have been apparent right across the achievement spectrum (Ainley et al. 1994; Fullarton & Ainley 2000), leading researchers (Goodrum et al. 2001) to note that it is unlikely that the lower participation rates can be fully explained by the wider range of abilities found in recent Year 12 enrolments, which have increased substantially since 1980 (Dekkers & DeLaeter 2001).

Of greatest concern to science educators have been the participation rates for the main public examination science subjects - physics, chemistry and biology - since these subjects are prerequisites for university courses traditionally leading to science related careers. Figure 2.1 illustrates the national enrolment trends in these subjects over the last two decades.

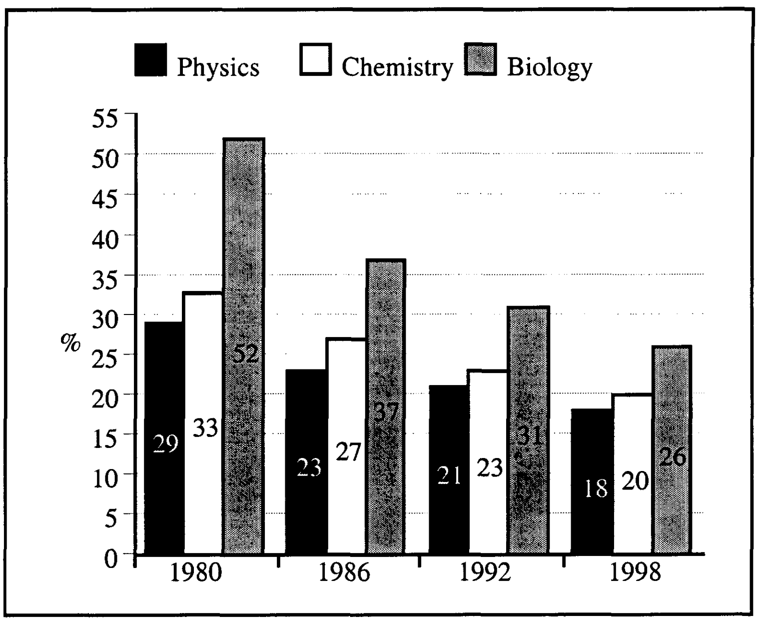

Figure 2.1 Enrolments in the main public examination science subjects. The figure shows percentages of Australian Year 12 students enrolled in physics, chemistry and biology courses since 1980 (adapted from Dekkers & De Laeter 1997, 2001; DeLaeter & Dekkers 1998)

Steady declines in participation are evident in all three subjects. Although inconsistencies have been noticed in data from different sources (ACDS 1999), the decreasing enrolments in physics, chemistry and biology have been found in both state and national data. For example, according to the Department of Education, Training and Youth Affairs (DETYA) Schools Division, national enrolments in physics, chemistry and biology, as a percentage of Year 12 cohorts, declined by 14 per cent, 16 per cent and 21 per cent respectively between 1991 and 1997 (ACDS 1999, p. 14). Enrolments in a fourth science option, geology, have declined to the point where very few schools in Australia continue to offer it as a senior course (Goodrum et al. 2001).

Dekkers and De Laeter (1997) acknowledged that while enrolments in these science courses fell, there were substantial increases during the same period in participation in alternative science courses such as Science for Life and General Science, as well as in school based science courses. Alternative and school based courses, often having a social or vocational focus, were introduced for students who did not need, or were not inclined to enrol in, the more rigorous science subjects required for university courses (Dekkers & De Laeter 2001). However, Dekkers and De Laeter (1997) expressed concern regarding the decline in enrolments in physics, chemistry and biology, since the smaller numbers of student who qualify to undertake tertiary courses in science, applied science and engineering courses may effect university enrolments levels and the supply of science graduates. The degree to which such observations have been validated by recent trends of supply and demand is discussed later in the chapter. For the moment these comments are reported in order to illustrate the level of concern accompanying these figures.

High School Science Concerns in New South Wales

The interpretation of statistics regarding science enrolment rates in NSW is problematic since, as noted above, there are variations between state and national data (ACDS 1999). Moreover, different studies categorise science enrolments in different ways, and changing curriculum structures have made it difficult to compare data from different periods. Nevertheless, figures drawn from a variety of sources all point to an enrolment decline in NSW greater than the national trend.

Studies by Ainley et al. (1994) and Fullarton and Ainley (2000) show NSW enrolments in senior science courses to have been consistently among the lowest in Australia (see Figure B.1, in Appendix B). In 1993, NSW had lower proportions of Year 12 enrolments than any other state or territory, in both the physical science and biology/other science categories used in these studies. By 1998, its relative position had improved marginally, only through greater declines in other states and territories (Fullarton & Ainley 2000). Figures taken from other sources confirm this trend, with NSW recording declines in Year 12 enrolments in physics, chemistry and biology of 30 per cent, 29 per cent and 24 per cent respectively, between 1991 and 1997 (ACDS 1999). In each case the decline was more severe than the national average. In 2000, the year students involved in the present study entered Year 12, HSC enrolments in physics, chemistry and biology were down to 15 per cent, 16 per cent and 24 per cent of the Year 12 cohort respectively (BoS 2000), continuing the trend of earlier years. These rates are far below any of the national data illustrated in Figure 2.1. Comparisons with more recent

NSW data are problematic, due to the restructuring of science courses for the 2001 HSC. Nevertheless, enrolments were again lower for physics (14 per cent), chemistry (15 per cent) and biology (20 per cent). Geology is no longer offered as a HSC course in NSW (BoS 2001).

These figures are symptomatic of deeper problems concerning NSW students' interactions with, and responses to, junior secondary science. Rosier and Banks (1990) examined the Australian data collected in the Second International Science Study (SISS) for statistical relationships between a range of factors, including student background characteristics, attitudes and aspirations, and scientific literacy. Relative to other states and territories, NSW science education did not appear in a particularly positive light. The study found that Year 9 (14 - 15 year old) NSW students' rated lowest of all Australian states and territories on a number of items, including the perceived relevance of school science to their lives (1990, pp. 110 & 113), the value they place on school science in terms of future job prospects in general (1990, p. 119), and the relevance of science to their personal career aspirations (1990, p. 119). The importance of students' perceptions of science, even at this early stage, cannot be understated. Woolnough (1994, p. 664) found in his study of factors associated with the choice of science careers, that for those who had made a decision towards, or away from, a career in science and engineering, 'many had done so before the end of Year 9, age 14.' Furthermore, in the study by Rosier and Banks (1990), students' responses to questionnaire items gauging perceptions of the value of science to society indicate that it is not regarded as highly valued or beneficial. To the item 'people who understand science are better off in our society', NSW students recorded the lowest percentage agreement of all the states.

It was not possible to follow up these findings with figures from the Third International Maths and Science Study (TIMSS), conducted in 1994, since to date the Australian data concerning students' attitudes to science had not been presented in a state by state comparison (see Lokan, Ford & Greenwood 1996). Nevertheless, there was little reason to think that the findings of Rosier and Banks (1990) would not be representative of the attitudes and perceptions of NSW students at the time of the present study, since there had been few changes to the junior secondary science curriculum in the intervening period (Secondary Schools Board [SSB] 1984, amended 1989, 1992).

Implications for the Future

The discouraging picture of NSW school science suggested by enrolment trends and student attitudes has important educational and social implications, discussed below. The first concerns the levels of scientific literacy that can realistically be attained by students who do not progress beyond Year 10 science and who, by the age of fourteen, see science as having little personal relevance. The second issue relates to the future of the scientific endeavour in Australia, and the problem of meeting demand for professional scientists.

Scientific literacy

Secondary science education in NSW aims to develop in students the ability to use the knowledge, skills and procedures of science in their life away from school or study (BoS 1998c). The previous syllabus (SSB 1984, amended 1989, 1992) also stressed the importance of teaching about the social relevance of science so that students learn to 'cope with the "knowledge explosion" and technological change' (1984, p. 2). These aims should be fundamental to the development of any scientifically literate and democratic society. As Fleming (1989, p. 393) observed:

> ... a technologically literate person has the power, and the freedom to use that power, to examine and question the issues of importance in socio-technology ... Being critical about technology means having the intellectual skills to examine the pros and cons of any technological development, to examine its potential benefits and to perceive the underlying political and social forces driving the development.

This promotion of the utilitarian and democratic benefits of a scientifically literate citizenry has been echoed by Leach (1996, p. 270), who made the additional case for science as 'an important cultural product ... in contemporary scientific and technological societies.' Yet, science education bodies in Australia anticipate 'a national crisis in the education of future generations' in terms of adequately preparing them for life in a technologically advanced world (AAS 1993, p. 53). Indeed, concern over the need for critical thinking skills goes beyond consideration of technological developments to epistemology. To give an example from one of the most technologically advanced nations in the world, Holton (1993, p. 148) revealed the uncritical acceptance of pseudo-science by US citizens, including the finding that 40 per cent of the adult population were willing to grant scientific status to astrology.

Drawing from the authors above, and others in the field (Cobern 1998a; Fensham 1996; Lee 1997; Millar & Osborne 1998; Solomon & Aikenhead 1994; Thomas & Durrant 1987), it is reasonable to conclude that students who see science as relevant, important and socially beneficial, and who continue with science at least to the senior secondary years, have a greater likelihood of helping form the scientifically literate society envisaged by Fleming (1989). This raises the question of the degree of scientific literacy that can be expected from a citizenry which, given the views of many NSW students, sees little personal and vocational relevance in the science experienced in secondary school. Rosier and Banks (1990, p. 25) concluded that some of the students who do not continue with the study of science at the upper secondary levels will have been exposed to a relatively limited range of science topics. Educators who emphasise the role of school science in realizing a scientifically literate society would not be encouraged by either the declining participation rates in post-compulsory high school science, or the attitudes to science expressed by Year 9 students.

Demand for scientists

A second concern about enrolment trends has been expressed in relation to specialist science vocations, particularly the ability of decreasing graduate numbers to meet the present and future demand for scientists. There have been general assertions of dire straits both in Australia (Australian Financial Review 14th June 1993, in NBEET 1994; Ridd & Heron 1998; Smith 1996) and overseas (Charles 1993; Reineker 1995, in Ridd & Heron 1998; Woolnough 1993), particularly from within the physics community. In the early 1990s, Australian physicists were making claims of an increase in projected demand due to a stagnating supply and the impending retirements of many of their number (AAS 1993). Their argument was also based on an Australian Science and Technology Council (ASTEC 1991) report claiming that, in terms of the proportion of physicists, Australia was well behind other industrialised (OECD) countries. This consternation was not shared by Australian chemists, who predicted for the year 2000 a supply able to cope adequately with projected demand (RACI 1993). Furthermore, with the exception of those involved in mining, it was acknowledged that there was also a slight negative demand for engineers (Adams & Meagher 1997).

More recent national data (Borthwick & Murphy 1998) indicate that supply and demand for scientists in general is fairly balanced and should remain so in the near future. There is little evidence of the 'increasing demand' for physicists predicted earlier this decade. In fact Borthwick and Murphy (1998, p. 19) concluded that, based upon current employment rates, there is at present a slight oversupply of graduates in the physical and life sciences, with demand exceeding supply only in computing science and mining engineering professions.

In view of these figures, concerns about enrolments based upon claims of a widening gap between demand for science graduates and supply, is less persuasive than that presented in support of scientific literacy. Nevertheless, it is not difficult to recognise the concerns of the scientific community for what it sees as the waning interest and involvement of young people in a field which it values greatly and in which the members have a cultural investment. This concern is indicative of the cultural characteristics of science, where members share a particular ontology, both professionally and personally, and react to perceived threats to the values of that 'worldview' (Cobern 1996). Thus, while not understating the concerns about supply of professional scientists, it is argued that concerns about scientific literacy in Australia constitute a more compelling reason for investigating science enrolment trends. As a former Minister for Science and Technology noted, given the pace of scientific and technological change, the scientifically illiterate may in the future be as cut off from the wider culture as those who have not learned to read or write (Jones 1986).

The importance of the implications discussed above have been recognised by a number of researchers, whose studies have sought to uncover the factors associated with high school science enrolment patterns. The findings and conclusions of these studies, discussed below, contributed significantly to the conceptual framework guiding this thesis.

INFLUENCES ON STUDENTS' SCIENCE ENROLMENT DECISIONS

The literature pertaining to the process of subject selection for senior school can be divided into three broad areas of investigation. First, many studies have focused on students' explanations for their various subject choices. A second body of research has investigated the sources of advice referred to by students during the deliberation process. Third, a small number of studies have sought to identify associations between students' background factors and science enrolment patterns. The relationships between these bodies of research, in terms of an overall conceptual framework for considering science subject choice, is illustrated in Figure 2.2.

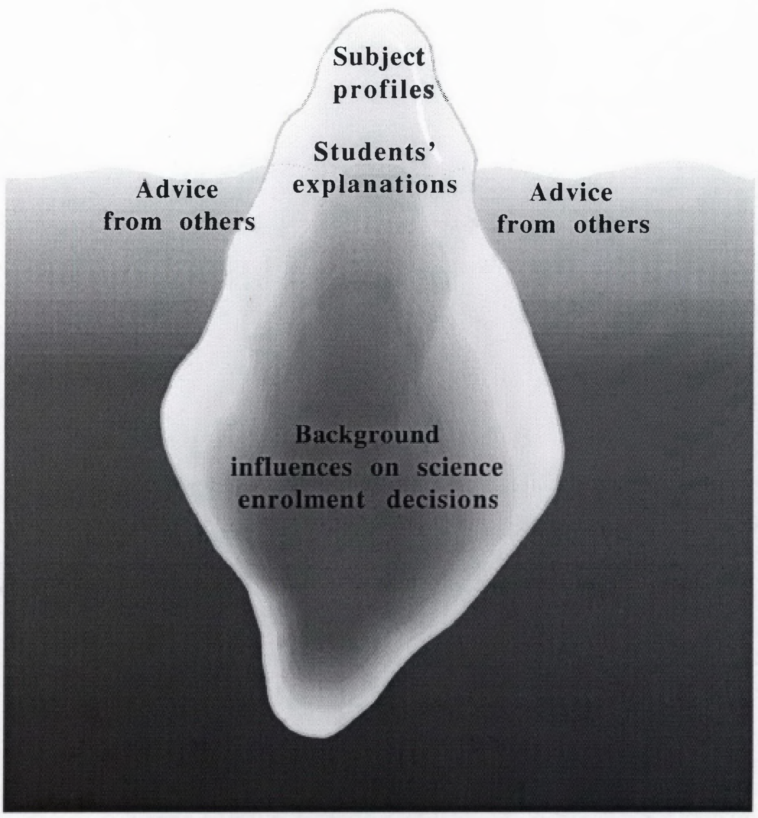

Figure 2.2 The foundation for an evolving conceptual framework. The diagram situates the topographical features of subject choice in relation to the less apparent influences on students' deliberations.

The metaphor of an iceberg has been used both to situate elements of the literature and to illustrate the thesis of this study; that many important influences on students' deliberations are obscure, complex and relatively unexplored, particularly in terms of their dynamics. Figure 2.2 depicts students' subject profiles, both individually and statewide, as observable and measurable phenomena. Likewise, it is relatively easy to survey students' explanations for their decisions and to have them identify their sources of advice. The position of this advice in the figure suggests that, while it is environmental, it can be incorporated into students' explanations. These three sets of information are important surface, or topographical, features of science subject choice in high schools. The influences on deliberation processes, on the other hand, are conceptualised in the diagram as less apparent and accessible. This iceberg metaphor is used throughout the chapter as an evolving conceptual framework.

Students' Explanations for Choosing Science Courses

In reviewing the most widely cited Australian studies on subject choice, it became apparent that all had relied upon primarily quantitative methodologies, basing their conclusions upon statistical analyses of large numbers of survey responses (Ainley et al. 1994; Barnes 1999;

Care & Naylor 1984; Fullarton & Ainley 2000; Haeusler & Kay 1997; Hobbs 1987; Kidd & Naylor 1991; Sleet & Stern 1980). The instruments used in these studies sought biographical data, or students' rationales for particular subject decisions, and usually provided a bank of limited options or Likert-type items. With some exceptions (e.g. Johnston & Spooner 1992; Mitchell 1997; Taylor 1983; Whiteley & Porter 1998), there has been little qualitative work done in Australia investigating subject choice, and no studies taking a substantially qualitative approach to the exploration of science enrolment decisions by NSW high school students.

The main explanations given by students for subject choices in general have included enjoyment of the subject, interest, relevance to work, requirements for further study, the usefulness/practicality of the subject and the anticipation of success in terms of marks (Ainley et al. 1994; Haeusler & Kay 1997; Hobbs 1987). With regard to science subjects, it was recognised that students' explanations for choosing physics were very similar to those given for choosing chemistry (Ainley et al. 1994; Fullarton & Ainley 2000; Haeusler & Kay 1997; Woolnough 1994). On the other hand, students choosing biology provided noticeably different explanations to those of physical science students, but similar to those of students taking other courses, such as Science for Life or General Science. As a consequence, most studies in this area (e.g. Ainley et al. 1994; Fullarton & Ainley 2000; Woolnough 1994) distinguish between two choice categories: physical science students and biology/other science students.

By far the most common explanations for choosing physical science subjects involved extrinsic motivations, such as future study or career aspirations (Ainley et al. 1994; Haeusler & Kay 1997; Khoury & Voss 1985; Sleet & Stern 1980; Wood & De Laeter 1986). In the study by Ainley et al. (1994) for example, over 50 per cent of physical science students nominated these reasons, a figure similar for both genders. However, only 7.5 per cent nominated their enjoyment of science as a motivation, the lowest percentage of all non-compulsory subjects.

In contrast, intrinsic reasons such as interest and enjoyment of the subject dominated for biology/other science students (Ainley et al. 1994; Sleet & Stern 1980). This intrinsic/extrinsic dichotomy of rationales pointed to a substantial difference in the educational orientations of students making different science enrolment decisions, with choices apparently being made on the basis of future or present benefit (Mitchell 1997). In the light of arguments for scientific literacy made earlier, it is also interesting to note that in one study (Ainley et al. 1994, p. 147), the option 'this subject is one I find useful and practical' rated last among both physical science and biology/other science students.

The studies cited above have contributed considerably to an appreciation of the rationales students' provide for their science enrolment decisions. However, a question raised regarding their collective strategies concerns the degree to which the students' responses represented accurate depictions of the influences on their decisions. Tuckman (1978, p. 197) made the point that such surveys assume, firstly, that respondents know why they acted in a particular way, and, secondly, that their responses reflect this knowledge and not what they think the researcher wants to hear. Kelly (1988, p. 8) also acknowledged the limitations of such methodologies, since 'children may not consciously know what influences them.' There may even be the impact of what Festinger (1964, p. 5) called 'post-decision dissonance reduction', whereby an individual justifies a choice which has excluded alternatives, by increasing the attractiveness of the chosen option and decreasing the attractiveness of rejected alternatives. While thorough planning and thoughtful presentation of a survey may to some degree ameliorate these concerns, there is always an element of doubt regarding the extent to which students' responses reflect the influences shaping their decisions. As research introduced in this chapter demonstrates, these doubts are supported by the recognition that particular decisions about science are associated with a variety of sociocultural factors. This is an association few students have recognised.

Gaining Advice on Subject Options

The process of choosing subjects for senior school is a novel situation for secondary students, and one often associated with a degree of apprehension (Mitchell 1997). It is understandable, therefore, that students often seek advice from a variety of sources. The consultation process has also been of interest to educators, particularly curriculum designers and career counsellors, who have investigated the sources and nature of advice provided and the degree to which this advice has impacted on students' decisions.

Haeusler and Kay (1997, p. 32) made the observation that research findings on consultation patterns have often been contradictory. For example, they cite studies which have found parental influence to be both preeminent (Abendroth 1985; Jones 1990; Wilson 1993) and of little influence (Beukes 1986; Garratt 1985). Likewise, peers have been found to be both highly influential (Jones 1990; Suda et al.1993) and insignificant (Beukes 1986; Wilson 1993). Panizzon (1995) found a similar divergence of opinion, citing Cohen (1983) and Dawson & O'Connor (1991) as concluding that peers had little influence on subject choices, and Astin and Astin (1992) and Scholer (1993) as supporting the opposite argument.

It is difficult to reconcile these alternative views, except to note that the findings often originated in different countries and involved students of different age groups, who were therefore at different stages of their education. For example, the students in the US study by Astin and Astin (1992) were in college and, as noted by McInerney and McInerney (1998), therefore more dependent on peers, and less on parents, than would be expected among younger students. Another intriguing explanation offered by Haeusler and Kay (1997, p. 36) is that many students do not use the same criteria in selecting different subjects. These authors found, in common with other studies (Ainley et al. 1994; Khoury & Voss 1985; Wood & De Laeter 1986; Woolnough 1994), that career aspirations were a major consideration for those choosing physical science, though not for those taking creative arts. However, Haeusler and Kay (1997) also found that peer opinions were far more influential in the choice of creative arts subjects than in the physical sciences, where advice was sought mostly from parents and teachers. Unfortunately, Haeusler and Kay (1997) did not investigate sources of advice for students choosing biology/other sciences, so it remains to be seen whether the dichotomous pattern noticed so far with respect to the different science courses, is supported in regard to enrolment advice.

A further consideration regarding the decision making process was not so much the sources of advice, but the extent to which advice was solicited. Warton (1997) surveyed over a thousand Year 10 students in NSW in order to investigate the sources of information and advice used when deliberating over senior subject choices. Her finding that parental guidance for both educational and vocational decisions was seen as more important than the views of friends (1997, p. 8) was consistent with previous studies (Wilks 1986; Wilks & Orth 1991). Indeed, friends were seen as one of the least useful sources of advice.

A criticism of Warton's (1997) study, and the majority of those cited above, is that they did not distinguish between the influence of fathers and mothers, a limitation that may mask differential relationships. Furthermore, Warton's findings did not indicate whether males and females had the same consultation patterns. Conclusions from a UK study by Kelly (1988, p. 16) suggested that this was not the case, at least when deliberating about taking physics. Kelly found that seeking advice was more important for females than for males. On the other hand, while Kelly (1988, p. 21) agreed that parental advice was considered to be more important than that of friends, she also found that it was more important than advice from teachers, a conclusion inconsistent with that of Warton (1997).

Thus, it appears from the literature that consultation patterns, and the usefulness of the advice received, may vary with educational context, the gender of the student and the particular subject under consideration. Furthermore, there are many gaps in the literature regarding deliberations about senior science enrolment by Australian students, and no studies specific to the consultation patterns of science proficient students. In terms of the present study, therefore, few assumptions could be made about the sources of direct influence on these students' decisions. As a consequence, while remaining cognisant of the findings discussed above, it became important to determine for this study's population both the origin of any advice students' sought or received, and the degree to which they relied upon it.

Teachers' Perceptions of Science Enrolment Decisions

Science teachers are in a unique position to observe and comment on the patterns they perceive in students' subject choices. Yet, there has been very little research soliciting teachers' opinions as expert witnesses. In one study, however, Woolnough (1993) canvassed head teachers of science in UK schools successful in producing physics and engineering candidates, as to their opinions why students decide for or against these careers. The teachers attributed very low levels of influence to the items 'home background/parents' and 'student's ability and interests', in comparison to the in-school items such as 'good science teaching' and 'good careers advice'. Furthermore, it was a common perception among these science teachers that students were encouraged by the inherent characteristics of physics, particularly the challenge of problem solving (1993, p. 115). Woolnough also found a belief among head teachers that students were discouraged from pursuing a career in science by the low salaries and status of science careers (1993, p. 116). This is a sentiment echoed by many Australian scientists (AAS 1993; Niland 1998; Ridd & Heron 1998) and one explored in the present study.

Comparisons between Woolnough's (1993) UK study and one involving Australian science teachers and students are, of course, problematic, not least because findings arising from studies concerning enrolment in physics cannot necessarily be generalised to other science subjects. Nevertheless, Woolnough's study was instructive in being one of the very few providing a teacher's perspective of students' decision making processes, and because of the contrast these findings presented in comparison to those discussed previously. In view of the dearth of research in this area, the present study undertook to survey science teachers as to their perceptions of the reasons why increasing numbers of 'science proficient' Year 10 students are deciding to forgo the further study of science subjects.

Background Influences on Science Enrolment Decisions

It was noted previously that most of the Australian studies concerning subject choice focused on topographical features: enrolment data, students' rationales, or information on their sources of advice. Very little research has attempted to investigate background influences on students' enrolment decisions. The studies making such an attempt have provided a perspective very different to that of teachers in Woolnough's (1993) study, by revealing the involvement of obscured and complex social influences, as implied earlier in Figure 2.2.

Perhaps the most influential of recent investigations into subject choice was that conducted by Ainley et al. (1994). Their extensive and illuminating research sought to provide a profile on subject choice by Year 11 and 12 students, using data collected in 1993 at the classroom, school and systemic levels across Australia. Ainley et al. (1994) determined that students' decisions about enrolling in science subjects were statistically associated with a number of factors, including socioeconomic background, parents' education levels, gender, ethnicity, earlier school achievement, geographical location and school type. Similar associations were found in a follow up study using 1998 data (Fullarton & Ainley 2000). Because of their implications for the present study, these associations are discussed in detail below.

Socioeconomic status

According to both studies (Ainley et al. 1994; Fullarton & Ainley 2000), enrolment in physical science was more closely associated with high socioeconomic status than was enrolment in any other subject area (see Figure B.2, Appendix B). The index of 'socioeconomic status' was based on the 'Australian National University Scale of Occupational Prestige' (Broom et al. 1977). The researchers collapsed the scale into four categories, labelled low (unskilled or semi-skilled), lower-middle (trades, clerical and sales), upper-middle (para-professional, small business) and high (professional). Year 12 students whose parents were in professional occupations, for instance, participated at greater than twice the rate of students whose parents were in semi-skilled or unskilled jobs. This was not the case, however, for biology/other sciences students, where enrolments were fairly consistent across all socioeconomic levels.

There is a good deal of evidence linking a range of school science outcomes to socioeconomic indicators. Some studies (Leslie, McClure & Oaxaca 1998; Woolnough 1994), like those above, have recognised the statistical relationships between enrolment in physical science and high occupational status of parents. Others have noted positive relationships between occupational status and both achievement in school science (Lokan et al 1996; Rosier & Banks 1990), and students' aspirations towards science careers (Mau et al. 1995; Woolnough 1994). Although some of the studies above speculated on the dynamics of these relationships, the nature of their methodologies constrained further explorations of cause and effect. This is a limitation common to many of the findings reported in this section, and one which is discussed in more detail later in the chapter. It is clear from the literature, however, that parents' occupational status, or some issue related to this characteristic, has the potential to affect students' deliberations about enrolment in senior science.

Levels of parental education

Enrolment in physical science subjects has also been shown to have a stronger association with levels of parental education than enrolment in any other subject area (Ainley et al. 1994; Fullarton & Ainley 2000, see Figure B.3, in Appendix B). This conclusion is supported by Woolnough's (1994) UK study, which discovered an association between parents' professions and students' aspirations to a career in physics. All three studies found little gender difference in these relationships. In contrast, no clear associations were found between parental education levels and the choice of biology/other sciences (Ainley et al. 1994; Fullarton & Ainley 2000). Parental education has also been implicated in students' achievement in science, with SISS and TIMSS results showing a strong positive correlation between these variables (Lokan et al. 1996; Rosier & Banks 1990).

Some studies have combined measurements of occupational prestige and parental education to form composite scales correlating more closely with educational outcomes. Keeves (1988), for example, made the point that a related index, 'sociocultural level of the home', is in many cases a better correlate with educational outcomes. Rather than being based solely upon occupational prestige, Keeves' index included the degree to which significant others in the home directly or indirectly encouraged education, particularly 'reading and the use of language' (1988, p. 468). This index also considered the education levels of parents. Keeves (1988) argued that it is a high 'sociocultural level of the home', often associated with high socioeconomic background, which influences educational outcomes, rather than occupational prestige *per se.* This argument suggests that the measurable variables discussed above are indicators of family culture, rather than direct influences on students' decisions. In view of this, the present study's investigation of family influence was designed to explore beyond such indicators, to the status given education, and science education, within the family culture.

Gender

Another factor found to have strong associations with science enrolment patterns was the gender of students. Ainley et al. (1994) noted that while enrolment figures for science in general did not differ greatly for males and females, a far higher proportion of physical science students (65 per cent) were male. In contrast, 60 per cent of students enrolled in biology/other sciences were female. By 1998, these proportions had changed little, although overall science enrolments were down (Fullarton & Ainley 2000). Gender differences have also been found in students' explanations for their science enrolment decisions. Kelly (1988), for example, noted that males and females often provided different rationales for choosing the same courses, with females more likely than males to explain decisions to take, or to drop, physics and biology in terms of their enjoyment of the courses.

Gender differences in students' engagement with school science have been the subject of a great deal of research. This has included investigations of enrolment differences (Johnston & Spooner 1992; Kelly 1988; Teese et al. 1995), the apparent role of physiological or cognitive differences (reviewed in Sjøberg & Imsen 1988), the gendering of science as male (American Association of University Women [AAUW] 1992; Harding 1996; Jones, Howe & Rua 2000; Kahle 1988; Kleinman 1998; Reiss 1993; Willis 1989), the influence of peers (Astin & Astin 1992; Holland & Eisenhart 1981; Panizzon 1995) and different parental expectations of sons and daughters (Eccles 1989). In her comprehensive review of the literature concerning females in school science, Solomon (1997) presented a strong case for sociological explanations of the disparate enrolment profiles of males and females. In particular, the evidence that science is gendered, both as a school subject and as a profession (Hegarty-Hazel 1997; Jones, Howe & Rua 2000; Kleinman 1998; Sjøberg and Imsen 1988), and the recognition that such gendering is a social construct, suggest again that culture and cultural practices play an important role in shaping students' engagement with school science.

Ethnic background

Students from non-English speaking backgrounds (NESB) have a greater tendency to choose the physical sciences than do those from an English speaking background, and are also less likely to enrol in biology/other sciences (Ainley et al. 1994; Fullarton & Ainley 2000; Hartley & Maas 1987; Myhill, Herriman & Mulligan 1994). This conclusion appears to have little interaction effect with gender. Although there has been little research on subject choice distinguishing between different NESB groups, a number of studies (Chan 1988; Fan 1996; Myhill et al. 1994; Schneider & Lee 1990) have found a strong tendency for students of Vietnamese and Chinese ethnic heritage to enrol in physical science subjects. While Myhill et al. (1994) suggested that high aspirations and a preference towards careers in engineering, health and science were influential in many NESB students' decisions, again there has not been a thorough exploration of the underlying motivations for science enrolment decisions among NESB students in Australia.

Some consideration needs to be given to the assumptions of studies which draw general conclusions about ethnic background and educational outcomes. Distinctions between ESB and NESB students, for example, are of limited value, since findings may be assumed by the researcher, or interpreted by others, as reflecting ethnic heritage rather that other salient influences, such as migration and settlement experiences or family cultures. Even when considering studies which do distinguish between different NESB groups, it should be recognised that making generalised associations between students' choices and the ethnic backgrounds of their families is a precarious approach, since it often assumes a degree of homogeneity unsupported by the literature (Hartley 1995; Hartley & Maas 1987; McDonald 1995; Ninnes 1997a; Ninnes 2002). The influence of cultural practices and values related to ethnicity are discussed further, in relation to findings from this study, in Chapter Seven.

School achievement

Strong, positive relationships have also been found between enrolment in the physical sciences and high levels of earlier school achievement in numeracy and literacy (Ainley et al. 1994; Fullarton & Ainley 2000; Haeusler & Kay 1997). In contrast, a slight negative correlation has been found between high achievement and enrolment in biology/other science subjects (Ainley et al. 1994; Fullarton & Ainley 2000). These relationships did not differ significantly with gender, though the negative correlation between high achievement and enrolment in biology/other science was mostly restricted to males. Ainley et al. (1994) offered the opinion that correlations between earlier achievement and the choice of more demanding science subjects implicated notions of aptitude and the sense of competence often associated with academic achievement.

Geographical location

With regard to the influence of school location, Ainley et al. (1994) found that although a similar proportion of rural students participated in the senior sciences as did their urban peers, there was a slightly greater inclination for the former to enrol in biology/other sciences, and for students in capital cities to enrol in the physical sciences. Students in non-capital cities had similar physical science enrolment patterns to rural students, though they enrolled less frequently in biology/other science. However, more recent data (Fullarton & Ainley 2000) show urban non-capital city residents to have the highest proportion of enrolments in biology/other science, while figures for physical science are similar for all three locations. Although not a direct indication of subject choice, a study by Young, Fraser and Woolnough (1997) found no significant differences between urban and rural students' intentions to pursue careers in science or engineering. These later findings cast doubt on whether location can be regarded as a reliable indicator of science enrolment decisions.

School system and school type

High schools in Australia generally belong to one of three systems. The majority are government schools, supervised by state departments such as the NSW Department of Education and Training (DET). Non-government schools are either systemic Catholic schools, or affiliated with the Association of Independent schools. Ainley et al. (1994, p. 85) found that students enrolled in independent schools had a higher participation rate in the physical sciences than did those in government or Catholic systemic schools, which both recorded similar enrolment figures. There was little difference across systems for participation rates in biology/other science subjects.

Each system includes coeducational and single-sex schools. Ainley et al. (1994) found that males enrolled at single-sex schools were equally inclined to choose physical science courses as those in coeducational schools, though there was a small difference between females in each school type. However, the authors noted that this difference was reduced once they had allowed for the socioeconomic differences between school populations (1994, pp. 120-121).

Students enrolled in single-sex schools tended to come from higher socioeconomic backgrounds, a factor strongly associated with the choice of physical science, as mentioned previously. Caution in attributing enrolment differences to the variable 'single-sex school' was also advocated by Johnston and Spooner (1992) for similar reasons. However, the same argument can reasonably be used to explain the higher physical science enrolment rates in independent schools, since students in these schools also tend to come from families with higher socioeconomic status. Thus, the degree to which school type is a direct influence on physical science enrolment remains unclear.

To summarise the findings detailed above, research clearly shows enrolment in physical science subjects to have a strong positive relationship with being male, coming from a family which enjoys high socioeconomic status, having parents who have completed formal education beyond the high school level, and coming from a non-English speaking background. It is also strongly associated with early proficiency in numeracy and literacy. The background factor most closely associated with choosing biology/other science was being female, though there was also a strong positive relationship with having an English speaking background. The choice of biology/other science was negatively associated with high levels of early school achievement in numeracy and literacy among males.

With the possible exception of early achievement, all of the factors mentioned above are directly related to students' sociocultural backgrounds. Even sex differences can arguably be attributed to social constructions of gender. Furthermore, it is not difficult to find links between sociocultural background and academic achievement. The recent TIMSS results, for example, showed that levels of student achievement in maths and science closely paralleled the occupational status and education levels of parents, and were associated with environmental variables, such as family size and the number of books in the home (Lokan et al. 1996). Such variables have long been found to correlate with students' levels of achievement (Keeves 1972; Marjoribanks 1979).

The strength of the relationships between patterns of science choice and family background makes a compelling case for the serious consideration of the sociocultural domain in any discussion of the enrolment deliberations of science proficient students. This is not to advocate a perspective attributing enrolment outcomes to purely social forces, as argued by Roberts (1975) or Woods (1976). The social determinism implicit in such approaches has since been satisfactorily challenged by others (Hodkinson & Sparkes 1997; Kelly 1988) as ignoring individual choice. Rather, the research summarised above shows the strength of arguments that a sociocultural exploration of the influences on science enrolment decisions offered the most promising avenue for this study to follow. Nevertheless, it was important to consider alternative models which have been used to explain subject choice, such as that discussed below.

Subject choice and personal interests

While acknowledging the important influence of background factors, Ainley et al. (1994) were drawn towards students' psychological characteristics as potential indicators of subject preference. In this they were motivated by earlier studies (Care & Naylor 1984; Kidd & Naylor 1991) that made use of Holland's (1985) typology of 'personal interests'. As this perspective offers a popular alternative to that taken by the present study, it is worth examining. Ainley et al. (1994, p. 127) understood personal interests to be 'psychological traits which activate and arouse individuals to respond to external objects or events'. These traits may be expressed as preferences for a particular occupation, school subject or activity. In their study, Ainley et al. (1994) identified students' interests according to their responses to schedule items on a Likert scale. The response patterns were then compared with Holland's typology. The authors concluded that interests were quite strongly and systematically associated with students' subject choices. With regard to enrolment in science, Ainley et al. (1994) concurred with the findings of Kidd and Naylor (1991) that Year 10 students who had expressed predominantly 'investigative' interests were far more likely to participate in science and mathematics in Year 11 than were students with other primary interest orientations.

These conclusions and their assumptions raise some important questions about the nature and origin of these psychological traits. One might query, for instance, whether personal interests should be regarded as innate, or as having developed in response to social influences. If the former, it is reasonable to ask to what degree psychological traits are subject to the vicissitudes of experience. Such questions have been raised by critics of personality theories in general, and Holland's approach in particular. Osipow (1973, p. 78), for example, claimed that the lack of a theoretical basis underlying the process of personality development is a 'serious deficiency'. Tuck and Keeling (1986, p. 12) also described Holland's typology as atheoretical, and questioned the claim that personality types result from a person's 'biological and social heredity, coupled with his personal history' (Holland 1966, p. 10). Tuck and Keeling (1986) also made the point that if personal history is influential in developing the personal interest type, then its nature must, by definition, be dependent on particular environments, and that personality types could therefore vary from one cultural group to another. Indeed, problems with the generalisability of Holland's typology across cultures, as noted by these and other researchers (Naylor & Mount 1986) suggest that environmental issues are in fact influential.

Ainley et al. (1994) did not dwell on the questions raised above, nor did they reconcile their conclusion that psychological factors predispose students to make particular decisions, with the finding that social factors were also strongly associated with decisions. Instead, the authors simply concluded that the psychological and sociological associations represented different perspectives on students' subject choices. This lack of reconciliation may have been due to the authors' aim of describing, rather than exploring, statistically significant relationships. In considering the conclusions of Ainley et al. (1994), however, the present study took the view that, given the strength of the many social background factors shown to influence decisions about senior science, and the apparent independence of these factors with respect to the intrinsic characteristics of the subjects, students' sociocultural backgrounds presented a more promising field for further investigation of their decisions.

Developing the Conceptual Framework

In summary, this review has considered a range of studies concerning science enrolment decisions, representing a number of perspectives. First, in terms of students' explanations for choosing science, there is a clear polarisation in the responses given by students choosing physical science subjects and those taking biology/other science. Whereas the former gave predominantly extrinsic, future orientated reasons, such as career and tertiary requirements, the latter group offered mainly intrinsic, present orientated reasons, such as enjoyment and interest. Such reasons were very seldom given by students explaining why they had taken physical science.

Second, studies investigating sources of advice involved in the decision making process produced variable and, in some cases, contradictory conclusions, implying that the dynamics of consultation vary with gender, educational context and subject area. Due to the importance of external advice in students' deliberations, this study therefore made no assumptions about the sources of advice consulted by science proficient students, choosing rather to investigate this as part of the study.

Third, background factors such as high socioeconomic status, high levels of parental education, non-English speaking background, and high levels of literacy and numeracy, had strong correlations with the choice of physical science, but not with the choice of biology/other sciences. These associations were, for the most part, independent of gender, though far fewer females than males tend to choose physics, and many more choose biology. These findings are intriguing not only because of the particular relationships, but for the fact that there should be *any* strong correlations between particular patterns of science choice and sociocultural factors. These associations constituted an important motivation and direction for the present study.

Finally, some studies consider psychological factors such as 'personal interests' to be predictors of subject choice. It was argued, however, that as the concept of personal interests is under-theorised, and their origin and nature questionable, there is doubt over the contribution they make to our understanding of students' motivations. As a consequence, this perspective falls outside the focus of this thesis.

In the light of these conclusions, the iceberg metaphor used earlier was developed more fully as a conceptual framework (see Figure 2.3), acknowledging both the layers of complexity, and the factors shown by research to be associated with students' decisions about enrolling in senior science subjects. However, the dynamics of influence are absent from this model. For example, there are no explanations of how gender or parents' education levels, for example, affect students' enrolment decisions. This absence is due, in part, to the limitations of the quantitative methodologies employed in the studies discussed above. These limitations were an important consideration in determining the approach taken by this study.

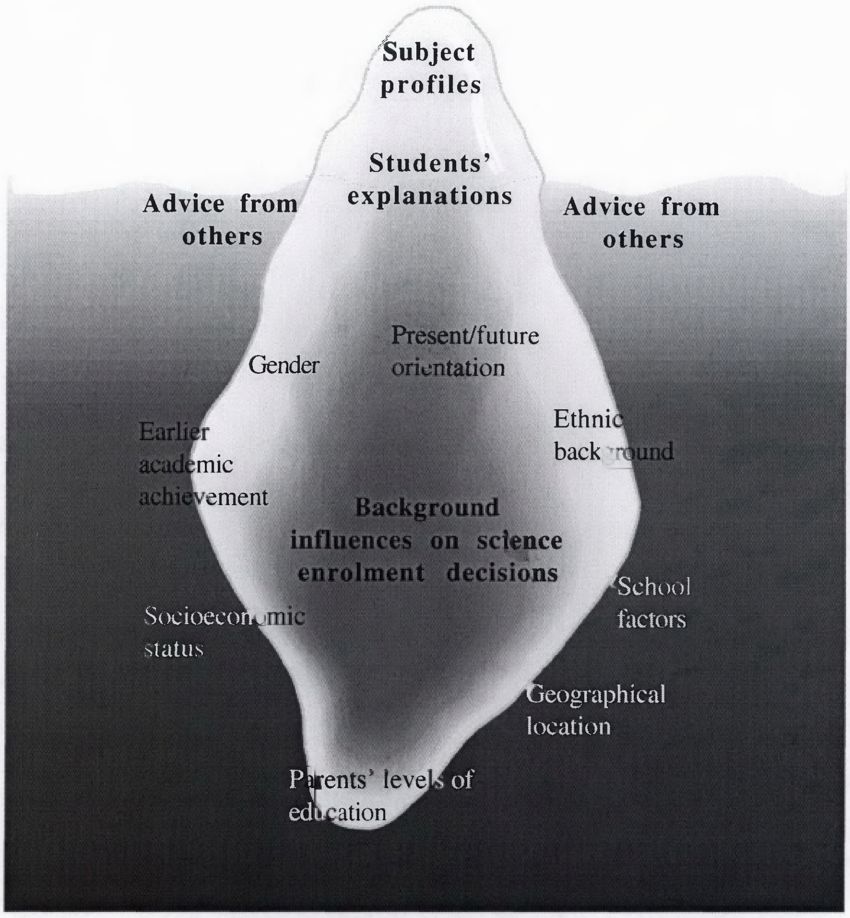

Figure 2.3 The conceptual framework. The framework has evolved from Figure 2.2 to reflect the sociocultural influences associated with science subject choice. The metaphor suggests a constant interaction between the individual and the environment whereby influences are complex, dynamic and often obscure.

THE OPPORTUNITY FOR A NEW APPROACH

The contributions of the studies discussed above to an understanding of the factors relating to science subject choice cannot be overstated. In particular, reference has been made extensively to Ainley et al. (1994), Fullarton and Ainley (2000) and Rosier and Banks (1990) because of the scope and relevance of their research. Nevertheless, it can also be argued that the requirement for statistical reliability in these studies has proven to be a limitation, in that the methodologies used to achieve it were necessarily restricted to types of data that can be quantified. This was acknowledged by Rosier and Banks (1990), who, in reflecting on their methodology, noted that the kind of information that can be collected by means of a self-completed questionnaire is limited. At best, they saw this approach as 'representing a surrogate' for more detailed investigations of interactions between students and their families (1990, p. 70).

Specifically, the closed nature of the quantitative methodologies necessitated limiting students responses to those which could be numerically coded. Such an approach excludes elaboration and restricts respondents to prescribed options. This is a disadvantage if the objective is to explore any relationship in depth. For example, in his investigation of students' enrolment motivations, Hobbs (1987, p. 34) recognised the limitations of his requirement for students to rank in order the reasons he had provided, acknowledging that such a methodology may not necessarily reveal the actual reasons, since these may be absent from the list, or interpreted in a variety of ways.

A further limitation of the factor analysis used in many of the studies is the requirement to collapse data into categories of statistically similar but phenomenologically disparate items. A factor is a useful pointer, a coarse indicator when viewing phenomena from a distance. Its function is 'to *impose* an orderly simplification' (Child 1970, in Cohen & Manion 1994, p. 330, emphasis added). Even at its most elaborate, factor analysis can only create an ersatz model of the real phenomena, and details which may be important in terms of meaning can be lost in the process.

There is also the matter of distinguishing between cause and effect and recognising, like Woolnough (1994, p. 675), that factors may interact in a cyclic rather than linear manner. Likewise, Young, Fraser and Woolnough (1997, p. 22) remarked that although many researchers study these effects separately, when investigating influences on decisions the variables are often interrelated and confounded. In particular, to assume that any of the aforementioned 'personal interests' (Ainley et al. 1994; Haeusler & Kay 1997) can be discussed without reference to sociocultural influences is naive, a point made by Solomon when she referred to 'the precariousness of personal choice' (1997, p. 412). Wood and De Laeter (1986, p. 288) also acknowledged that a significant factor associated with students' choice of physics, which they identified as 'personal or internal influences', was itself likely to have arisen from the influence of parents, science teachers and guidance officers.

These points, in concert with the criticisms made earlier, highlight the methodological limitations of the quantitative research reviewed above. It is perhaps ironic that while many of the authors have acknowledged the complexity of the issues involved in choosing senior subjects, their research has sought to simplify students' deliberations in the interests of external validity. It is the contention of this thesis that much of importance can be lost in this process, and that, for the present study, an alternative approach was needed to build on the quantitative research, while at the same time providing a more meaningful interpretation of the influences on science proficient students' enrolment decisions.

The perspective taken by this study was that science enrolment decisions could best be understood by exploring the influences within students' sociocultural domains to fathom not only the value systems referred to in making subject choices, but also the origins of, and influences on, these systems. As Solomon (1997, p. 412) argues:

> We need to reflect much more on ideas like the construction of personal choosing and cultural persuasion, much less on the apparently simple notion of liking or finding interesting some aspects of science. Choice on a matter so important and so public as what school subjects are studied, and hence what school classes are to be attended, is self-defining in important ways.

While advocating a sociocultural perspective, this study does not suggest that investigation of students' backgrounds can provide a complete picture of the influences on their decisions. Culture is not always the most significant issue (McConaghy 1998). Cognitive differences, school structures, maturity and opportunity may all have a role in students' final decisions. Rather, the thesis argues that the sociocultural domain provides a rich and, in this context, relatively unexplored field for research. Its exploration, however, requires a map - a theoretical model - developed in stages throughout the discussion below.

Students' Sociocultural Domains

One difficulty in exploring a student's sociocultural domain lies in conceptualising it. A model which attempted this was constructed by Phelan, Davidson and Cao (1991, see also Phelan, Davidson & Yu [Cao] 1998), who offered it as a representation of the interrelationships between students' family, peer and school contexts and the boundaries students perceive between these 'multiple worlds' (see Figure 2.4). The model was developed inductively from research data, as well as being guided by theoretical perspectives, notably those of cultural compatibility theorists such as Erikson (1987) and Spindler (1987).

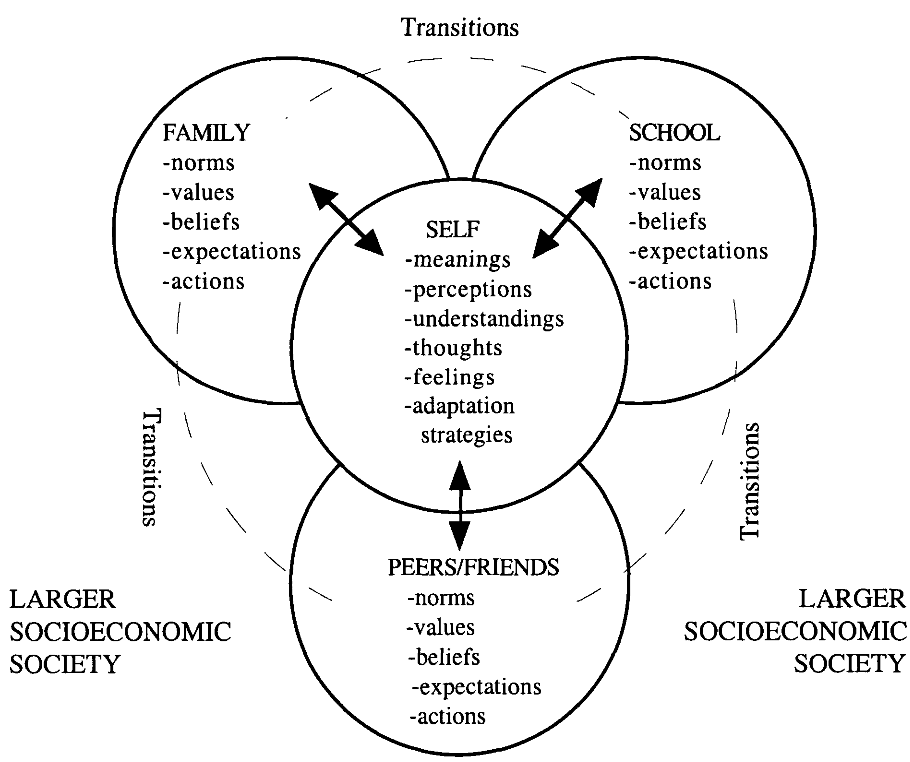

Figure 2.4 A model of the interrelationships between students' 'multiple worlds' of family, peer and school (Phelan, Davidson & Cao 1991, p. 228).

The multiple worlds model conceptualised students' day to day activities as involving transitions between worlds in which different cultural knowledge and modes of behaviour exist. In particular, Phelan et al. (1991) were interested in the various degrees of difficulty students experience in crossing borders between these worlds, and the adaptation strategies employed in coping with these difficulties. The authors conducted interviews with senior high school students in California in order to examine school factors affecting their engagement with learning (1991, p. 227). The use of open-ended interviews allowed students to talk about other features of their lives, (including peers and family), relevant to their feelings about school. This approach resulted in a more comprehensive understanding of 'the individual as *mediator* and *integrator* of meaning and experience' (Phelan et al. 1991, p. 226, their emphasis), an outcome which has influenced the present study to adopt a similar investigative strategy.

The students' responses led to the development of a typology of border crossing patterns and adaptation strategies dependent upon degrees of congruency between cultural features of different worlds. Culture was considered to include the norms, values, beliefs, expectations and conventional actions specific to a world (Phelan et al. 1991). In relation to the typology, worlds which were culturally congruent enabled smooth transitions. For example, where the culture of a student's home world harmonised with that of school, transition was uncomplicated. In general, the greater the cultural incongruity between worlds, the more difficult the border crossing. The four patterns are indicated below:

Type I:	Congruent Worlds/ Smooth Transitions
Type II:	Different Worlds/ Boundary Crossings Managed
Type III:	Different Worlds/Boundary Crossings Hazardous
Type IV:	Borders Impenetrable/Boundary Crossings Insurmountable

(Phelan et al. 1991, p. 228)

The typology is not discussed at length here, as it has since been modified in relation to science education; a development described below. However, of note was the claim that the typologies, and indeed the model, 'transcend ethnic, achievement and gender categories' (Phelan et al. 1991, p. 228). Prior to this model, there had been little research examining interactions between student and contextual influences in an holistic manner (Steinberg et al. 1988). The conceptualisation of this interaction by Phelan et al. (1991) therefore represented an important contribution to the sociology of education literature.

In relation to the present study, however, of greater relevance was the subsequent research by Costa (1995) who appropriated this model in conceptualising students' interactions with school science. Costa saw these interactions in terms of students' transitions between worlds which may have different expectations:

> What goes on in high school science classes is somehow considered independent of the adolescents' worlds, as though students leave their personal life at the door of the classroom and take it up again like a backpack when they leave.
>
> (Costa 1995, p. 331)

Costa's study described a model for understanding how students' different experiences of, and responses to, school science are related to the degrees of congruency between their worlds of family, friends, school and science (1995, p. 313). Like Phelan et al. (1991) before her, Costa developed the model in the light of data generated by in-depth interviews with high school students. In focusing on the 'meaning-perspectives' (1995, p. 330) of 43 science students, she identified five categories which, to some extent, paralleled the multiple world typology:

'Potential scientists':	Worlds of family and friends are congruent with worlds of both school and science.
'Other Smart Kids':	Worlds of family and friends are congruent with world of school but inconsistent with world of science.
'I don't know' students:	Worlds of family and friends are inconsistent with worlds of both school and science.
'Outsiders':	Worlds of family and friends are discordant with worlds of both school and science.
'Inside Outsiders':	Worlds of family and friends are irreconcilable with world of school but potentially compatible with world of science.

(Costa 1995, p. 316)

These categories do not correspond directly to those of Phelan et al. (1991) since Costa's aim was to look for similarities and differences between students, rather than to try to fit them into a pre-defined typology (1995, p. 315). Costa also noted that students did not necessarily fall into the same categories for the same reasons, since not all worlds showed the same degrees of congruence for each student.

The present study was particularly interested in Costa's first two categories, as these related to science proficient students. The 'potential scientists' were identified by their recognition of school science as a passage into the scientific community, and by the high degree of congruence between their family and peer worlds and those of school and science (Costa 1995, p. 317). The second category, 'other smart kids' (a term Costa borrowed from Tobias 1990), included students who were as successful in school and science courses as potential scientists, but who 'did not see science as intrinsically meaningful' (Costa 1995, p. 319). Unlike the 'potential scientists', this group had no aspirations to continue with science study beyond high school, despite having demonstrated the proficiency to do so. Costa attributed this decision to perceived incongruencies between the world of science and the students' worlds of family and peers (1995, p. 330). Thus, the differences between 'potential scientists' and 'other smart kids' were, first, the degree to which the culture of science was seen to be congruent with their family and peer cultures, and second, the abilities of different students to negotiate their ways between these worlds.

The proposition that students' science experiences and aspirations were associated with congruence or incongruence between different worlds suggested a new way of looking at the problem of declining enrolments in science. It raised the question of the degree to which decisions about enrolling in science courses might be explained in terms of cultural incongruence. Certainly the proposition was consistent with research on science enrolment patterns showing sociocultural characteristics of students' families to be implicated in their decisions. In addition, Aikenhead (1996) argued convincingly that the model was consistent with a number of significant theoretical perspectives within the field of science education. Thus, the aim of the present study was to explore the subject deliberations of science proficient students, and to determine the degree to which cultural congruence and incongruence were implicated in their various decisions regarding further science study. However, before applying the model to a new context, a number of important issues needed to be addressed.

Conceptions of culture

The first concern was the description of culture initially applied by Phelan et al. (1991), and subsequently interpreted as a definition by Aikenhead (1996, p. 8). Phelan et al. (1991, pp. 225 & 228) were careful not to attempt a comprehensive definition of culture, but rather to presume that each world contained constructs, such as norms, values, beliefs, expectations and conventional actions, familiar to insiders. Culture is a difficult concept to define (Keesing 1981) and attempts to do so are often too prescriptive, or so amorphous as to be of little practical use. As this difficulty is due in part to the ways in which culture is conceptualised in different academic disciplines, a study such as this, which engaged the fields of science education and educational anthropology, faced particular problems. Nevertheless, this study followed the example of Phelan et al. (1991) in identifying key constructs which characterise or distinguish cultures, rather than attempting an all encompassing definition. In addition to the constructs specified by Phelan et al. (1991), this study considered the culture of each world to also be shaped by formalised influences, such as social structures and artifacts (Kroeber & Kluckhohn 1952), by economic and cultural resources (Bourdieu & Passeron 1977), and by personal relationships and interactions (Coleman 1988; Cooper & Denner 1998; McLaren 1991).

The absence of a rigorous cultural checklist meant that systematic explorations of, and comparisons between, the various cultures of students' multiple worlds, were problematic. To address this difficulty, a useful analytical framework was developed based upon the work of Keeves (1972, 1975), who conceptualised students' home, peer and school environments as having structural, attitudinal and process dimensions. In the present study, structural features were considered to be the overarching frameworks affecting conditions within students' worlds. These frameworks differ from world to world. Family structures, for example, include the size of the family, the parenting structure, and the occupations of parents (Keeves 1975; Marjoribanks 1979, 1987, 1995), whereas school science worlds are structured by curriculum guidelines, external examinations, resources, timetables and subject prerequisites (Chadbourne 1995; Fensham 1992; Mitchell 1997; Whiteley and Porter 1998). Examples of peer world structures are the size and number of a student's peer groups, their gender and ethnic compositions (Panizzon 1995), and whether they are school based. On the other hand, the structural features of students' mass media worlds incorporate the media formats with which each student is able to engage, and access to science related material.

The attitudinal dimensions of the different worlds are less diverse, comprising the values, beliefs, attitudes, aspirations and dispositions held by individuals within each world (Bennett 2001; Osborne, Driver & Simon 1998; Ramsden 1998; Saha 1997; Simpson & Oliver 1990). Examples from the different worlds include family cultural values (Mak & Chan 1995; Ninnes 1997b), beliefs about the value of science courses (Head 1985; Johnston & Spooner 1992; Maddock 1981), the attitudes of friends to different subjects (Stables & Stables 1995), or the images of scientists promoted through fictional television programmes (e.g. Schibeci 1986).

Due to conceptual and methodological differences between Keeves' (1972) work and the present study, the term 'dynamic' was preferred to his term 'process'. While processes within each world were salient to the study, the new label emphasised the importance of personal interactions and relationships, as noted above. Dynamics within the various worlds include family and peer relationships (e.g. Bradley & Corwyn 2000; Coleman 1988; Panizzon 1995), common practices within science classrooms (Apple 1992; Waldrip & Fisher 1998), or students' patterns of engagement with different mass media (Chen 1994).

It should be recognised that the three dimensions merely constituted a framework to help organise analysis and discussion. In reality, the cultures of students' worlds are organic, and many of the cultural features of different dimensions inextricably entwined. For example, a construct such as 'values', which is notionally part of the attitudinal dimension, was often influenced by, or had implications for, structural and dynamic aspects of a student's world.

Cultural boundaries

A second concern was that the multiple worlds model, and Aikenhead's (1996) definition of culture, implied that culture is static and determining, shaping those within it, while at the same time providing criteria to include or exclude individuals. From a postmodern perspective, culture and identity are seen as being far more dynamic than they are commonly conceptualised in educational research (McCarthy 1998; McLaren 1991). In particular, McCarthy (1998, p. 160) argues that students are themselves 'active producers and agents of culture'. As such, they are also agents of production within their own subcultures, formatting their family, peer and school worlds with reference to each other. A criticism which might be levelled at the model constructed by Phelan et al. (1991) is that the three worlds appear to have well defined borders and, although students move between the worlds, the suggestion is that they are exclusive sub-cultures within the 'larger socioeconomic society.' As borders are key to the model, it is worth discussing the way they have were conceptualised in the present study.

Students' worlds, like cultures more generally, should not be regarded as isolated, bounded and cohesive meaning systems (McLaren 1991). This view is supported by Gates (1995) and McCarthy (1998), who both emphasise the interpenetration of cultures, a concept which can also be extended to the multiple-worlds model. McCarthy notes of cultures in proximity that their 'very definition depends on the existence [of] and interaction with the other' (1998, p. 155). Therefore, despite the limitations of diagrammatic analogies, students' worlds were viewed by the present study as blending irregularly, and often imperceptibly, into each other. A less distinctly bounded model, however, presents difficulties with regard to identifying the origins or locations of particular influences. This difficulty is clearly reflected in the non-linear structure of this thesis, which constantly cross-references from one chapter to another. Nevertheless, to treat students' worlds as discrete locations, like separate rooms in a house, is to impose a conceptualisation which neither reflects contemporary interpretations of culture, nor accurately represents the findings of this study.

The idea that students' worlds are separate from 'larger socioeconomic society', as implied in the multiple worlds diagram (Figure 2.4), is also perhaps misleading. Because they are systems of meaning, cultures cannot be ontologically separated from economies of privilege and politics (McLaren 1991). This thesis took cognisance of the insights of Gates (1995), McCarthy (1998) and McLaren (1991) in assuming far more porous boundaries between worlds, and recognising that influences and elements of 'larger socioeconomic society' are found within each world. The model used by this thesis also acknowledged students' roles in influencing both the boundary conditions and cultures of their worlds.

The importance of cultural and social capital

A third observation concerns the articulation of conclusions drawn by Phelan et al. (1991) with other theoretical perspectives. In particular, their findings, and those of Costa (1995), demonstrated the influence of what Bourdieu and Passeron (1977) referred to as 'cultural capital', though neither Phelan et al. (1991) nor Costa (1995) made explicit reference to this concept. Bourdieu and Passeron (1977) used the term to describe the cultural goods transmitted by families in the context of education, or 'pedagogic action' (1977, p. 5). While cultural capital may be objectified in books and other educational materials, it is also symbolic, being institutionalised in credentials or degrees, or embodied as dispositions, aptitudes, knowledge or forms of language (Collins & Thompson 1997). The resources of cultural capital accumulated and valued by parents, and transferred to children, are therefore often associated with socioeconomic background, ethnicity, parental education and other demographic characteristics (MacLeod 1987). Bourdieu and Passeron (1977) argued that children whose families have provided them with the types of cultural capital valued by schools, are privileged in terms of accumulating further capital in the education system (Blackledge & Hunt 1985; Collins & Thompson 1997). However, because schools tend to be conservative institutions which value the cultural capital of dominant groups, the forms of cultural capital of minority or dominated groups are often ignored or otherwise devalued in schools.

Instances of the privileging, or marginalising, of different forms of cultural capital were apparent in many of the cases discussed by Phelan et al. (1991). For instance, in one case used to illustrate congruence/smooth transitions between family and school worlds, the authors noted that the 'teachers' language and communication style, conceptions of the necessary strategies for success, such as compliance, hard work and academic achievement and pervading upward mobility norms', matched the beliefs, values and behaviours found within the student's family (1991, p. 230).

The reference in the previous paragraph to forms of language recalls Bernstein's (1971) concept of 'restricted' and 'elaborated' language codes. Bernstein argued that children who are familiar with the elaborated code of language, characterised by explicitness, objectivity, formal syntax and the ability to express abstract ideas (Bernstein 1971; Cruttenden 1979) are better placed for educational success than those who use a restricted, or informal (Cruttenden 1979) language code. This is because the elaborated code is more often used, and given greater value, in the formal education system. Thus, language codes can also be seen as forms of cultural capital.

Costa's (1995) study demonstrated that school science has its own cultural capital, which may be congruent or incongruent with that valued within students' family or peer worlds. One of Costa's interviewees even used a metaphor of linguistic difference, describing chemistry as being 'like Japanese' (1995, p. 324). It follows, therefore, that any consideration of whether congruence or incongruence between different worlds may influence the enrolment decisions of science proficient students should be mindful of the types and resources of cultural capital within these worlds.

Phelan et al. (1991, pp. 229 & 242) also referred to family cohesiveness, family conflict, and the effect of such relationships on particular students. These references to family relationships resonate with Coleman's (1988) emphasis on the importance of 'social capital' within families. Coleman described a family's social capital as inhering in the relations between children and parents, with childrens' educational outcomes being influenced by the amount of social capital available. The availability of this capital is affected by a number of characteristics of family relationships, including the trustworthiness of family structures, the time parents devote to their children (Coleman 1988), and the efforts of parents in helping overcome obstacles for their children (Coleman 1990). Neither Phelan et al. (1991) nor Costa (1995) used the term social capital, and it is not a concept which has previously been linked to students' science enrolment decisions. Nevertheless, the examples provided in the two studies, and the influence of social capital on other educational outcomes, suggested that it might play some role in the subject deliberations of science proficient students.

Arguments for the inclusion of a mass media world

A fourth concern regarding the model constructed by Phelan et al. (1991) was that it was limited to the three worlds of family, peers and school. The supposition that these were the only fields of influence continued as a feature of the model following its adoption by Costa (1995) and Aikenhead (1996). However, research has shown that students' responses to science may also be influenced by the images of science and scientists propagated through the mass media (Basalla 1976; Chen 1994; Gerbner 1987; Long & Steinke 1994; Ormerod et al. 1989). The influence of television on students' engagement with science is also an issue which has been raised in respect of a perceived lack of fictional role models involved in scientific pursuits (NBEET 1994). Although the mass media is not a world through which adolescents move physically in the course of their activities, they are nevertheless exposed to cultural constructs such as norms, values, beliefs and expectations, produced and disseminated by elements of the mass media in relation to a number of conceptions, including science. Furthermore, as Radford (1996) recognised, most of what people know about anything beyond their work, family and, in this case, school horizons, is derived from press, radio and television. The present study therefore extended the framework to include a fourth world, acknowledging the role of the mass media as potential agents of influence.

Defining peers

Determining which individuals belonged to a student's peer world was problematic, given the widely divergent definitions of peer used in the literature (e.g. Astin & Astin 1992; Haeusler & Kay 1997; Stables 1996). Indeed, Holland and Eisenhart (1981) discussed peers in terms of a continuum, extending from 'informal equals' such as friends, to formal equals' such as classmates. However, the context of the present study helped limit the range of possible inclusions, since capacity to influence subject decisions was a vital consideration. Peers were therefore defined as persons of a similar age to the student, who were not family relatives, and who had the potential to influence, directly or indirectly, that student's science enrolment decisions. This included, but was not limited to, science classmates, networks of personal friends, and even students in Years 11 or 12 who provided enrolment advice.

Science, school or school science?

A final consideration was Costa's (1995) conceptualisation of the world of science. Costa referred to her students as having experience of both the world of science and the world of school. In particular, she noted that her 'other smart kids' had been 'put off' further engagement with the world of science (1995, p. 319). Yet, it is unclear whether these students were rejecting the world of generic science, or science as a career option, or the world of school science. Costa often used the terms *science* and *school science* interchangeably, possibly because her 18 year old students might be expected to have had a greater awareness of science as a career path, and the courses themselves to have a greater career orientation. However, the same cannot be said of 15 or 16 year old students in NSW, whose perceptions of science, both as an endeavour and as a career, are, for the most part, shaped by their experiences of school science.

School science differs culturally from both science as a research endeavour (Aikenhead 1996; Hawkins & Pea 1987; Shashank 1997) and school more generally (Siskin 1991; Waldrip & Fisher 1998). This thesis therefore considered a world of 'school science' to be a more salient field of investigation than one of 'science', given the context of progression (or not) from one level of school science to another. With regard to the terminology used in this thesis, *science* or *generic science* refers to the scientific endeavour more generally and its catalogue of knowledge and processes. A student's world of school science, on the other hand, is an amalgam of their experiences within laboratory or classroom environments, with a variety of teachers and classmates, over a number of years. These experiences include both explicit and implicit manifestations of the curriculum. To this extent it is, like other worlds, an internal, ongoing construction of each student (Hilton-Brown & Hagen 1999), whose perceptions and responses are influenced by aspects of his or her sociocultural domain (Costa 1995; Evans & Fisher 2000; Levy, Wubbels, Brekelmans & Morganfield 1997; Rickards & Fisher 1999).

School science is both situated in, and different from, other experiences of school. As Driver, Asoko, Leach, Mortimer and Scott (1994, p. 11) have pointed out, 'learning science in the classroom involves children entering a new community of discourse, a new culture.' Nevertheless, the boundary between school and school science was conceptualised in the present study as a very porous one, with structural, attitudinal and dynamic features of school providing a context for, and permeating throughout, the school science world. Although many influences, such as school structures, careers counselling and examination requirements, originate outside students' school science worlds, they can be seen as shaping those worlds to the extent that they contribute to students' experiences of, or deliberations about, further engagement with school science.

In view of the considerations above, the model proposed by Phelan et al. (1991) was modified to better suit the present study (Figure 2.5). The modifications included the specification of a 'school science' world, the addition of a 'mass media' world, and less definition in the boundaries between worlds. The cultural features of students' worlds were also less prescriptive than in the model developed by Phelan et al. (1991), being included under the general headings of structural, attitudinal and dynamic dimensions. Finally, no reference was included to 'larger socioeconomic society', since it was assumed that the influences of such a construct are pervasive and manifest within each of the students' worlds.

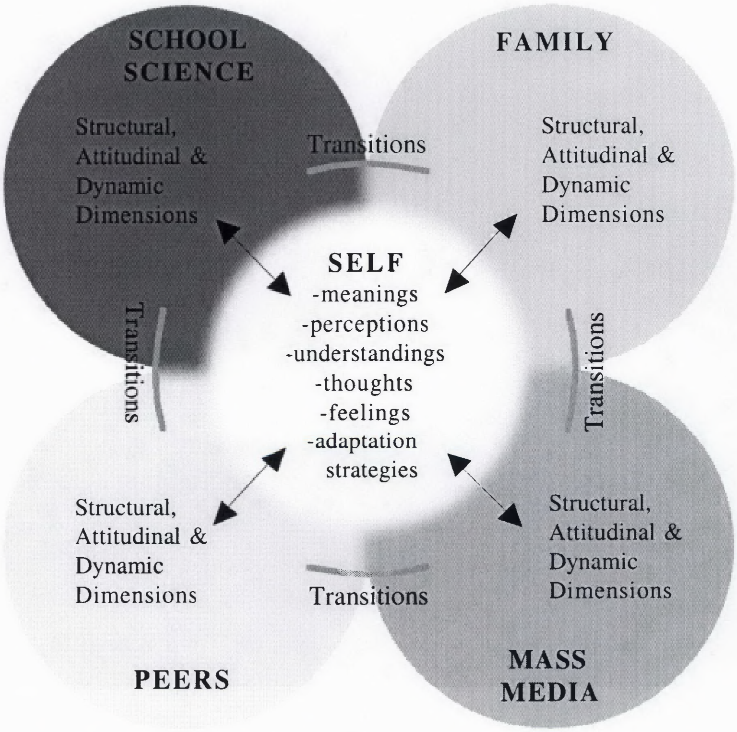

Figure 2.5 A new model of students' multiple worlds. In their transitions between worlds of family, school science, peer and the mass media, students' are required to negotiate structural, attitudinal and dynamic features of the culture of each world (adapted from Phelan, Davidson & Cao 1991, p. 228).

The inclusion of the mass media world created a schematic difficulty in that there appear to be no transitions possible directly between the family and peer worlds, nor between the school science and mass media worlds. This is really a limitation of the two dimensional representation rather than of the model itself. A three dimensional model, in which each of four spherical worlds is in contact with the other three, was conceivable, but presented practical difficulties in terms of clearly labelling and situating components. As a consequence, the study used the two dimensional representation.

Conceptions of, and Responses to, Science

Having developed an elementary model conceptualising the sociocultural domain of students lives, it was necessary to situate within it the possible influences on their science enrolment deliberations. Foremost among these were the conceptions of science held within each of the worlds. This inclusion acknowledged the view that science is not an immutable entity, but rather a cultural construct (Baker & Taylor 1995; Gough 1998; Maddock 1981; Pomeroy 1994; Reiss 1993) which can be interpreted and presented in many ways. Science as presented in schools, for example, may be different to the way science is conceived by elements of the mass media, or within the home. Conceptions of science also vary with ethnic culture (Atwater 1993; Hodson 1993; Ogawa 1986). Thus, in constructing their own pictures of, and ideas about, science, students are open to the influence of conceptions held within their worlds. As Head (1985, p. 1) noted:

> ... science is conceived, understood and propagated by individual persons whose understanding cannot be divorced from the totality of their beliefs and knowledge.

If this is interpreted in terms of the worlds in which students engage with science, then it follows that students learn more than just the science content. Packaged with the concepts will be some indication of the values, beliefs, and expectations of the person imparting the content, be they parent, science teacher, television producer or friend. The logical extension of this argument is that each of these individuals has a personal conception of science which includes their attitudes to science, and which may differ from that of others. For example, a science teacher may have different expectations of science, and accord it different status, than might be the case in a student's family. Likewise, the conventional actions of scientists in fictional television shows may be different to conventional actions of university scientists. Thus, the different cultures of the multiple worlds extend to conceptions within those worlds, including that of science.

To represent this idea in relation to the present study, the model was further developed to show how students' conceptions of, and responses to, science are influenced by the conceptions of science within each world (see Figure 2.6). While not ignoring the other cultural features of the worlds, the diagram illustrates how students' perceptions of the ways science is conceived by others in his or her social network may influence personal conceptions of science.

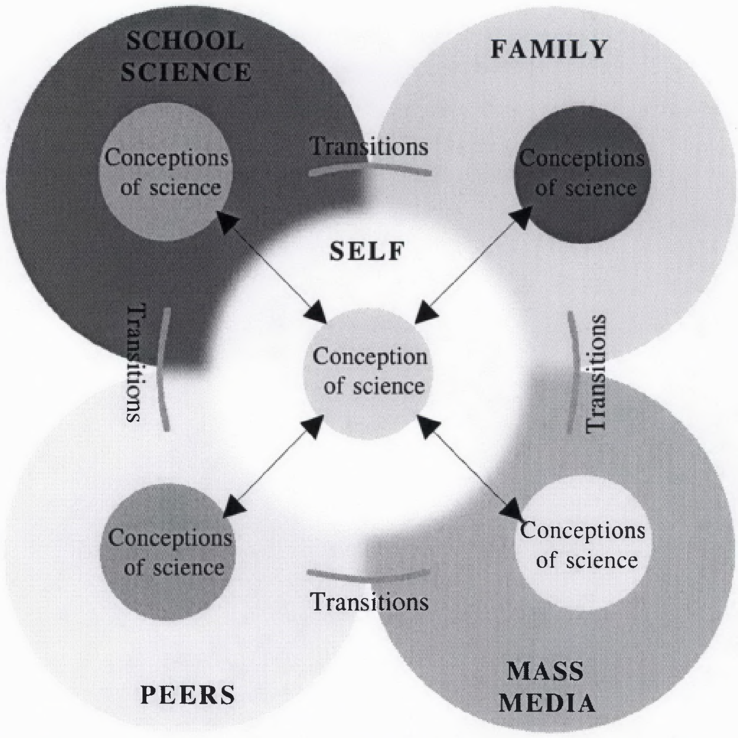

Figure 2.6 The social construction of students' conceptions of science. The multiple worlds model has been altered to show how students' own conceptions of science are constructed with reference to the conceptions held within their various worlds. The sociocultural context of each world mediates the process of construction. The cultural dimensions from Figure 2.5 are no longer shown, but assumed at this stage.

The mechanics of this influence, as represented by the arrows, were not discussed by Costa, though she did make reference to 'the construction of knowledge' (1995, p. 314). In order to develop this aspect of the model, it was important to theorise the crucial questions of how individuals may construct their own conceptions, and how this process may influence their responses to school science.

Constructing Personal Conceptions of Science

Arguably the most fundamental development in western education during the last century was the shift in focus from content to learner (Cleminson 1990; Shapiro 1988). In particular, an evolving realisation of the role of social influences on the learner and the process of learning has led to the reconceptualisation of learning models to include context and social interactions as integral to the process. One important model which has come to the fore, particularly in science education literature of late, is that of social constructivism.

Social Constructivism

Briefly, constructivist theory argues that a person internally constructs new concepts based upon the understandings they already hold. Driver (1988) maintained that individuals construct mental models of their environment and, in the process, interpret new experiences with reference to existing mental models, or schemes. Social constructivism is an extension of this theory, acknowledging that the process of constructing meaning is always embedded in the particular social setting of which the individual is part (Duit & Treagust 1995). This idea can be traced back to Vygotsky (1960, 1978), who theorised that children construct knowledge through the use of cultural inventions, such as tools, social structures and language. Vygotsky referred to children as being 'wrapped around by their culture' (McInerney & McInerney 1998, p. 38), and to learning as being culturally shaped by the social environment in which it takes place (Smagorinsky 1995). A related Vygotskian theme was that, rather than learning being a process of knowledge transfer, it occurred through the internal construction of a student's perception of external concepts. Vygotsky explained this in terms of a child's learning:

> Any function appears twice, or on two planes ... It appears first between people as an intermental category, and then within the child as an intramental category.
> (Vygotsky 1960, in Scott 1996, p. 326)

In reference to science education, then, scientific concepts are not simply transferred from teacher to student, but internally constructed by the student in relation to prior understandings and experiences. Furthermore, these concepts are constructed with reference to the student's perceptions, not only of the idea being discussed intermentally, but also the social setting and social interactions involved (Scott 1996; Solomon 1987). This dynamic is the basis for social constructivist approaches to science education.

However, if this process is extended beyond discussion of specific science content to students' conceptions of science itself, it can be argued that these are also associated with particular social contexts, since they are constructed from what students perceive of the conceptions held within the worlds through which they move. The social context includes the cultural features specific to each world. For example, a student may perceive that science is held in high esteem by her parents, but is regarded as irrelevant by her peers. In this situation, social constructivist theory suggests that the value accorded science in each of these worlds would in some way be reflected in the student's personal conception of science (Cobern 1998b; Solomon 1987). The social construction of students' own conceptions of science is thus open to conflict. Costa (1995) and Phelan et al. (1991) refer to incongruence between cultural features of different worlds as producing discord in students. In the constructivist literature, this discord is similar to a condition known as cognitive dissonance (Festinger 1957).

Cognitive dissonance

The process of constructing knowledge involves the interpretation of new data in the light of existing conceptions, an approach which, in the constructivist ideal, leads to conceptual change. As mentioned above, this process may involve situations in which the new and the existing explanations are contradictory. Though cognitive conflict is usually discussed in relation to the learning of new concepts (Duit & Treagust 1995; Scott, Asoko & Driver 1992) it can also be extended to the wider sphere of students' decision making. Phelan et al. (1991, p. 227) used the example of a case where a student's parent emphasised school achievement while his friends devalued good grades. The authors concluded that students must incorporate and manage these different perspectives while deciding on their own course of action. The cognitive conflict, or cognitive dissonance (Festinger 1957, 1980), produced by such a situation can be described as a 'sensed internal discrepancy between a conception and another entity, observation or other conception' (Rea-Ramirez & Clement 1998, p. 12). This thesis contends that cognitive dissonance, and its opposite, resonance, are indicative of what Costa (1995) and Phelan et al. (1991) describe as incongruence and congruence between world cultures. It is conceivable that the decision making process regarding senior science courses is one occasion in which the reconciliation described above by Phelan et al (1991) is required. Certainly, research has shown that dissonance may be strongly felt during consequential moments in life, such as when making major decisions (Misiti & Shrigley 1997). Therefore, this study sought to explore the degree to which dissonance and resonance were evident in the deliberations of science proficient students regarding further science study.

SUMMARY

This research was motivated by the increasing tendency for Year 10 students in NSW to forgo further science study. It has been argued that this trend has negative implications in terms of scientific literacy, both for the students themselves and for Australian society in the longer term.

In order to provide a context for this problem, three facets of students' science enrolment patterns have been discussed. First, it was recognised that the explanations students most often gave for enrolling in senior science differed according to the type of science course chosen. Second, the literature concerning the advice sought by students when making their decisions about science was found to be inconclusive, since consultative behaviour varied with context and the particular subject under consideration. It was therefore concluded that little about the consultation processes of NSW Year 10 students with regard to science could be assumed from prior studies. Third, studies of the background profiles associated with patterns of enrolment revealed that particular decisions about senior science were related to a range of social and cultural factors, suggesting strongly that sociocultural influences play an important, and often unrecognised, part in students' deliberations.

While conclusions from these bodies of literature related to a wider population than the science proficient students constituting the focus of this thesis, in the absence of other research on such students these conclusions provided a broad conceptual framework. In considering the literature, the argument was advanced that the investigation of students' sociocultural backgrounds constituted the most promising direction for future research. In conceptualising the sociocultural domain of students' lives, the study drew upon the work of Phelan et al. (1991) and Costa (1995) for two important contributions to this further exploration. The first of these was a sociocultural model conceptualising students' engagement with school science as being influenced by the cultural characteristics of their family and peer worlds. This model has been adapted to better suit the context of the present study. The second contribution was Costa's conclusion that cultural congruence and incongruence between students' worlds was important in influencing the different responses to science of her high achieving students. This finding prompted the present study to investigate the extent to which cultural congruence played a role in the decisions made by science proficient Year 10 students in NSW about enrolling in senior high school science courses.

DEVELOPING THE RESEARCH QUESTIONS

In the light of the discussions undertaken in this chapter, the focus returns to the first thematic research question, posed in Chapter One:

> What are the influences on science proficient students' decisions about enrolling in senior high school science courses?

In addressing this question, the study took the view that a triangulation of perspectives would provide both an insight into teacher and student perceptions, and a guide to further exploration via interviews. Hence, two specific questions were also posed:

> 1a) What are science teachers' perceptions concerning the influences on science proficient students' decisions to forgo senior science?
>
> 1b) What explanations do science proficient students give for their decisions about enrolling in senior science courses?

With regard to the iceberg metaphor, the specific questions above were meant to survey the topography of science subject choice, and thereby provide clues to the less apparent influences on students' deliberations. The deeper exploration was guided by the second thematic question, which involved the sociocultural model discussed above:

> Does cultural congruence or incongruence between the different worlds of science proficient students play a part in their science enrolment decisions?

More specifically, the study was concerned with particular science enrolment outcomes:

> 2a) Is cultural congruence influential in decisions by science proficient students to enrol in senior science courses?
>
> 2b) Is cultural incongruence influential in decisions by science proficient students to forgo further science study?

As noted in the previous chapter, the model used in this study allowed exploration of each world, as well as comparisons between worlds. Thus, in addition to identifying individual influences, the study was able to explore the interaction of influences and the congruence or incongruence which students' negotiations of their worlds may generate. The processes involved in planning and undertaking these explorations are described in detail in the following chapter.