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The Puzzle of Falling Enrolments in Physics and Chemistry Courses: Putting Some Pieces Together

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Abstract. This paper reports and discusses the principal findings of an Australian study exploring the decisions of high achieving Year 10 students about taking physics and chemistry courses (Lyons, 2003). The study used a ‘multiple worlds’ framework to explore the diverse background characteristics that previous quantitative research had shown were implicated in these decisions. Based on analyses of questionnaire and interview data, the study found that the students’ decisions involved the complex negotiation of a number of cultural characteristics within their school science and family worlds. Many of the students regarded junior high school science as irrelevant, uninteresting and difficult, leaving them with few intrinsic reasons for enrolling in senior science courses. The study found that decisions about taking physical science courses were associated with the resources of cultural and social capital within their families, and the degree to which these resources were congruent with the advantages of choosing these courses. The paper concludes that the low intrinsic value of school science and the erosion of its strategic value contribute to the reluctance of students to choose physical science courses in the senior school.

Key Words: cultural capital, family influences, school science experiences, science enrolment, social capital

Introduction

Over the last two decades, science educators in Australia have watched with growing concern the steady decline in the proportion of high school students choosing senior science courses. Between 1990 and 2001, for example, Year 12 (final year) enrolments in physics, chemistry and biology courses decreased by 23, 25 and 29%, respectively (Fullarton, Walker, Ainley, & Hillman, 2003), prompting questions about future levels of scientific literacy and technological expertise.

These issues, and concerns in other countries about similar trends, have prompted a number of investigations into the enrolment decisions of students entering senior high school. The studies identified significant relationships between science enrolment patterns and an eclectic range of factors, including achievement levels, gender, ethnic identity, personality traits, parents’ education levels, and socioeconomic status.

In terms of understanding how students decide about taking science courses, these findings present something of a puzzle. Apart from the strengths of the correlations, little is known about the relationships between these factors, and how, or indeed whether, they influence students' subject choices. While the more comprehensive of the studies (e.g., Barnes, 1999) have been able to attribute relative weightings to some factors, there has only been speculation as to how the pieces of the puzzle fit together. To a large extent, this is due to the quantitative methodologies such studies employed, and the absence of a comprehensive framework with which to examine students' enrolment deliberations in closer detail.

This paper reports the principal findings of my doctoral study (Lyons, 2003), which focused expressly on the enrolment decisions of high achieving (or 'science proficient') Year 10 students in New South Wales (NSW), Australia. This group was of interest for three reasons. First, concern has been expressed about the 'declining interest by bright students' in the further study of science (Niland, 1998, p. 3), since future generations of scientists, health professionals and engineers are generally drawn from those proficient in science at high school. Second, it has been shown that enrolment in physical science courses is statistically associated with higher academic achievement in junior high school (Ainley, Robinson, Harvey-Beavis, Elsworth, & Fleming, 1994; Fullarton & Ainley, 2000). By restricting the population to students who have already demonstrated the potential to successfully undertake these courses, the study was able to look for influences other than academic ability. Third, students coming to the end of Year 10 have their first opportunity to decide about further participation in science courses, following almost four years of compulsory multi-strand science education.

While the study also investigated decisions about biology, this report focuses on decisions about physics and chemistry courses. The paper begins by introducing the context of the study and discussing its relationship to previous research. This discussion outlines the argument for the novel approach taken in exploring students' science enrolment decisions, and details the antecedents of the framework used in this study. In reporting and discussing the substantial findings, extensive use is made of narrative extracts in order to present the students' perspectives on their experiences, and their interpretations of the deliberation process. On the basis of these findings, the paper proposes a model that describes these deliberations as they relate to physical science enrolment.

Context of the Study

Enrolment Declines

The decline in enrolments in high school physics and chemistry classes in Australia has been well documented. Figure 1 (adapted from Dekkers & DeLaeter, 2001) shows how enrolment rates in these courses decreased relative to total Year 12

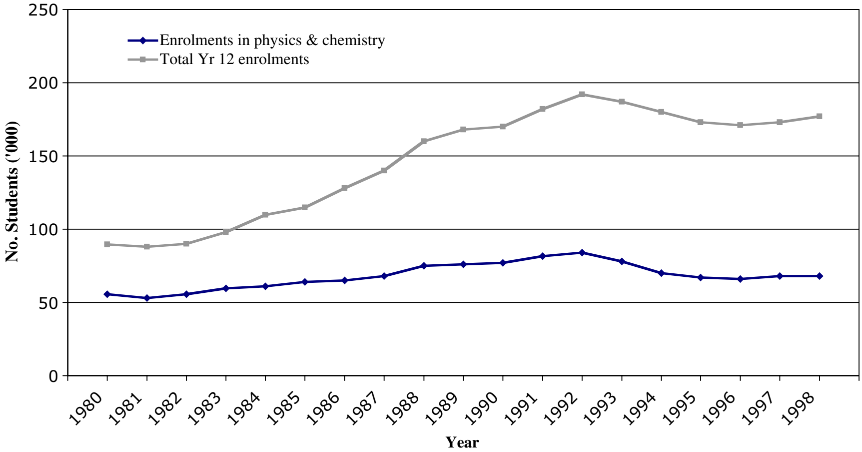

Figure 1: Comparison of Australian Year 12 enrolments in physics and chemistry courses (combined), with total Year 12 enrolments 1980–1998 (adapted from Dekkers & DeLaeter, 2001).

enrolments between 1980 and 1998. While Year 12 enrolments almost doubled during this period, enrolments in physical science courses increased by only 22 per cent. According to Fullerton et al. (2003), the proportions of Year 12 students taking physics and chemistry courses declined a further 17% and 12%, respectively between 1998 and 2001.

In NSW, physical science enrolment rates have been consistently below those of most other Australian states and territories (Ainley et al., 1994; Fullarton & Ainley, 2000). Between 1991 and 2004, for example, the proportions of NSW Year 12 students choosing physics and chemistry fell by 32% and 38%, respectively (Barnes, 1999; Board of Studies, 2004). While other science subjects, such as Science for Life, General Science and Senior Science have also been available, these are not regarded as 'enabling sciences' since they are not often taken by students who go on to university science courses. Rather, it is the increasing reluctance of students to choose physics, chemistry and to a lesser extent, biology courses in their final years of secondary education that has important implications not only for the health of scientific endeavour in Australia, but for the scientific literacy of future generations.

Considering the scale of the decline and its implications, there has not been a great deal of research undertaken to identify its causes. Studies that have addressed this issue can broadly be divided into three types. First, there are those which examined students' background characteristics for correlations with science enrolment patterns. A second type of study focused on students' explanations for their various subject choices. The third type were concerned with relationships between personality traits and subject preferences.

Background Characteristics

Perhaps the most comprehensive of recent investigations into subject choice have been the ACER longitudinal reports on Year 12 subject choice (Ainley et al., 1994; Fullarton & Ainley, 2000; Fullarton et al., 2003). Analysis of Australian data collected in 1993, 1998 and 2001 provide comprehensive statistical profiles of subject choice by senior high school students. The studies report that enrolments in science courses are strongly associated with a number of background factors, including gender, socioeconomic status, parents' education levels, and ethnic identity.

Gender

The ACER studies found consistent associations between science enrolment patterns and gender, with males constituting between 62% and 65% of all physical science students. In contrast, females make up about 60% of Year 12 biology/other science students.

The different science choices made by males and females have led to research on a range of issues, including enrolment behaviours (Johnston & Spooner, 1992; Kelly, 1988), the gendering of science as male (Harding, 1996), and parental expectations of sons and daughters (Eccles, 1989). In particular, the evidence that science is gendered, both as a school subject and as a profession (Solomon, 1997), and the recognition that such gendering is a social construct, support the argument that culture and cultural practices play an important role in shaping students' engagement with school science.

Socioeconomic Status and Education of Parents

According to the ACER studies, and research in the USA (Leslie, McClure, & Oaxaca, 1998) and UK (Woolnough, 1994), the choice of physical science is more closely associated with high socioeconomic status (based on parental occupation) than any other subject area. This is not the case, however, among biology/other sciences students in Australia, as enrolments tend to be fairly consistent across socioeconomic levels.

The ACER studies also reported that enrolment in physical science subjects was more closely related to higher levels of parental education than enrolment in any other subject area. In contrast, no clear associations were found between parental education levels and the choice of biology/other sciences. Again, these correlations are consistent with overseas studies (Woolnough, 1994).

Ethnic Background

Australian students from Asian backgrounds have a far greater tendency to choose the physical sciences than do those from other backgrounds, and are also less likely to enrol in biology/other sciences (Fan, 1996; Fullarton et al., 2003). This conclusion appears to have little interaction effect with gender. Chinese and Vietnamese Australian students, in particular, often regard high academic achievement and acceptance into prestigious tertiary courses as the principal ways of expressing filial piety and repaying the sacrifices made by immigrant parents (Mak & Chan, 1995; Ninnes, 1997). Other research indicates that many such students choose mathematics and science courses to minimise their exposure to English intensive subjects (Tobin & McRobbie, 1996).

In summary, robust correlations have been found between enrolment in physical science subjects and being male, coming from a family which enjoys high socioeconomic status, having parents who attained a university degree, and coming from particular ethnic backgrounds. In contrast, the factor most closely associated with choosing biology is being female, though there is also a strong positive relationship with having an English-speaking background.

Students' Explanations

Research has shown consistently that students tend to explain the choice of both physics and chemistry courses in terms of strategic needs, such as university study or careers (Ainley et al., 1994; Barnes, 1999). On the other hand, students generally give intrinsic reasons for choosing biology, such as interest and enjoyment (Fullarton et al., 2003). This extrinsic/intrinsic dichotomy of rationales points to a substantial difference in the educational orientations of students making different science enrolment decisions, with choices apparently being made on the basis of either future or present benefit.

While students' explanations might appear to clarify a significant part of the enrolment puzzle, this research approach is not without criticism. The main concern is the degree to which students' explanations accurately reflect the range of influences on their decisions. For example, in drawing conclusions about her own research in this area, Kelly (1988) acknowledged the limitations of relying solely on post-facto explanations, since students may not consciously recognise what has influenced them. In addition, conclusions from research based on students' explanations are inconsistent with the correlations found with background factors. For instance, there are no reports in the literature of students explaining their decisions about taking physical science courses in terms of their parents' socioeconomic status, or levels of education, despite the strong correlations found with these factors. Thus, conclusions from research based on students' explanations tend to be inconsistent with more evidential pieces of the puzzle.

Personality Types

A number of Australian studies (Ainley et al., 1994; Barnes, 1999; Kidd & Naylor, 1991) have reported links between students' decisions about science enrolment and their personality types. These studies were influenced by Holland's (1985) typology of personal interests, which have been described as 'psychological traits which activate and arouse individuals to respond to external objects or events' (Ainley et al., 1994, p. 127). In regard to enrolment in science, the studies reported that students who had predominantly 'investigative' interests were far more likely to participate in science and mathematics in Year 11 than were students with other primary interest orientations.

However, such conclusions raise important questions about the nature and origin of psychological traits. One may 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. Critics of personality theories in general, and Holland's approach in particular, have raised similar questions. Osipow (1973), for example, saw the lack of a theoretical basis underlying the process of personality development is a serious deficiency. Tuck and Keeling (1986) described Holland's typology as atheoretical, questioning his claim that personality types result from a person's biological and social heredity, coupled with his personal history. Tuck and Keeling also made the point that if personal history is influential in developing personal interest types, then this development must be affected by environmental factors, 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.

Studies in this area generally do not dwell on the questions raised above, nor do they reconcile the psychological predispositions of students with the strong sociological associations described in the previous section. Given the reliability and consistency of these associations, and the questions raised about personality theories, I concluded that students' sociocultural backgrounds presented the most promising avenue for further investigation.

A New Framework

A common feature of the majority of studies discussed above is their use of quantitative methodologies involving large numbers of survey responses. With the notable exception of Johnston and Spooner's (1992) study, there has been little qualitative research done in Australia to investigate science subject choice. Despite the valuable contributions of the ACER studies, they have not been able to clarify just how the background factors identified relate to students' decisions about further science study. What all of the researchers agree upon, however, is that the web of influences on students' enrolment decisions is indeed very complex.

This complexity, and the strong relationships between students' subject choices and their background characteristics suggested the need for new research to take a sociocultural approach. My study adapted the 'multiple worlds' model (Figure 2) developed by Phelan et al. (1991) to investigate influences within the students' family, peer and school worlds.

This model conceptualises students' day-to-day activities as involving transitions between these worlds, wherein they negotiate the different cultural knowledge and modes of behaviour. In particular, Phelan et al. (1991) were interested in the various degrees of difficulty students experienced in crossing borders between these worlds, and the adaptation strategies employed in coping with these difficulties. They found that where school and family worlds were culturally congruent, students' transitions between the worlds were unproblematic. Incongruence between school culture and peer or family culture, on the other hand, made transitions difficult.

The usefulness of this model in the domain of science education was demonstrated by Costa (1995), who reported that the ease or difficulty students experienced in crossing borders between school science and their family and peer worlds students' affected their engagement with the science curriculum. My study

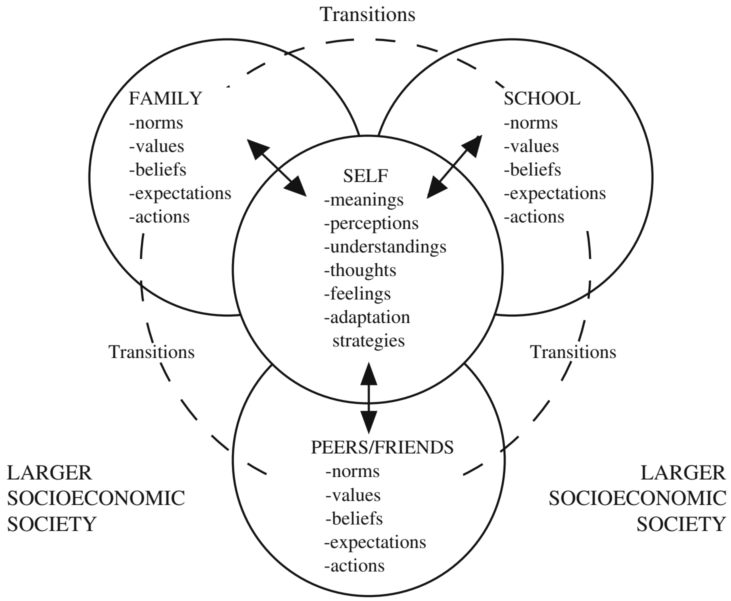

Figure 2: A model of the interrelationships between students' 'multiple worlds' of family, peer and school (Phelan, Davidson, & Cao, 1991, p. 228).

was interested in the degree to which such border crossing dynamics might also affect intentions to enrol in science courses.

The model developed by Phelan et al. (1991) was modified in a number of ways to better suit the context and the research focus (Figure 3). First, I included a 'mass-media' world, recognising the possible influence of mass media images of science or scientists on students' conceptions of science suggested by other research (Chen, 1994; Long & Steinke, 1994). While 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 values and beliefs, produced and disseminated by elements of the mass media in relation to a number of conceptions, including science. Furthermore, it is arguable that most of what students know about science beyond school, peers and family comes from mass media sources.

Second, the intersections between worlds were blurred to better represent their porous and ill-defined boundaries (McCarthy, 1998). Third, I distinguished between the structural, attitudinal and dynamic characteristics of each world, to provide a framework for analysing and comparing different cultural characteristics. The structural dimension refers to overarching contextual features affecting

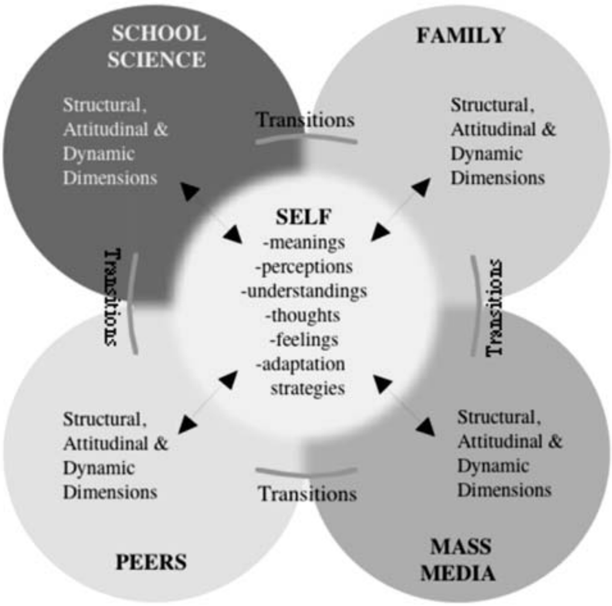

Figure 3: A theoretical model of students' multiple worlds (Lyons, 2003). In their transitions between worlds of family, school science, peer and the mass media, students' are required to negotiate structural, attitudinal and dynamic features of the culture of each world (adapted from Phelan, Davidson, & Cao, 1991).

conditions within students' worlds. In the students' family worlds, for example, structures include family constitution, parenting structures, and the occupations of parents. Their school science worlds are structured by curriculum guidelines, external examinations, timetables and subject prerequisites. The attitudinal dimension includes the various beliefs, attitudes and values concerning science and education prevailing in the different worlds. Dynamics include processes and relationships, such as science classroom interactions, family or peer relationships, and patterns of engagement with different mass media. The three dimensions are not substantially different from the cultural characteristics used by Phelan et al. (1991), and merely constituted a framework to facilitate analysis. In reality, the cultures of students' worlds are organic, and many features of different dimensions inextricably entwined.

The conclusions of Phelan et al. (1991) and Costa (1995) regarding congruence of cultures, and the subsequent conceptual development of these conclusions by Aikenhead (1996) suggested the influence of what Bourdieu and Passeron (1977) refer to as cultural capital. This term describes the cultural goods transmitted by parents to children in the context of education, or pedagogic action. Cultural capital may be objectified in books and other educational materials, although it is often symbolic, being embodied as dispositions, aptitudes, knowledge or forms of language, or institutionalised in credentials or degrees (Collins & Thompson, 1997). The resources of cultural capital accumulated and valued by parents, and transferred to children, are therefore often associated with socioeconomic background, ethnic identity and parental education, three pieces of the science enrolment puzzle. Bourdieu and Passeron argued that children whose families provide them with those forms of cultural capital valued by schools were privileged in terms of accumulating further capital in the education system.

Phelan et al. (1991) also referred to the effects of family cohesion and conflict on students' engagement with school. Such references to family relationships resonate with Coleman's (1990, 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 children's educational outcomes being influenced by the amount of social capital available. The availability of this capital can be affected by characteristics of family relationship such as the trustworthiness of family structures, the time parents devote to their children, and the efforts of parents in helping overcome obstacles for their children.

Methodology

The study used a multi-method approach involving both methodological and data triangulation. The initial phase of data collection included two survey questionnaires. The first was given to 196 Year 10 students (15–16 years) from six high schools representative of the most common types found in urban and rural NSW.

These included three coeducational government schools, two coeducational non-government schools and a non-government girls' school. Only those students who had achieved an 'A' or 'B' grade in School Certificate science, placing them in the top 30 per cent of the state cohort, were included in the study. All of the students had recently chosen courses for their final two years. The second survey sought the opinions of their science teachers ($n = 24$) as to enrolment trends in their schools, and their ideas about why senior science courses are becoming less popular. Findings from these surveys were explored in the second phase of the study, which involved in-depth interviews with 37 of the students, including 14 choosing physical science courses, nine taking biology/general science, and 14 deciding not to continue with science.

The student questionnaire sought biographical data and course enrolment details, and asked about the sources of advice students had accessed when making their subject choices and the degree to which they had relied upon this advice. To give an indication of students' levels of self-efficacy, they were also asked to rate their own abilities in science relative to their peers, and to indicate how they thought their science teacher might rate their abilities. Statistical analysis of the questionnaire data looked for significant relationships between background characteristics, subject choices, and sources of advice.

The interviews explored potential influences on students' enrolment decisions within their school science, peer, family and mass media worlds. NUD*IST software facilitated constant comparative analysis of the interview data, identifying patterns between students' descriptions of these worlds and their enrolment decisions.

The decision to focus primarily on students' perceptions of their worlds and their deliberations and was made for three reasons. First, it was assumed (and later supported by interview data) that the vast majority of students in this study ultimately made their own enrolment decisions, based upon their perceptions. Hence, the degree to which their perceptions varied from those of parents, teachers or peers was largely irrelevant to this study. As Levy, Wubbels, Brekelmans, & Morganfield (1997) argued in their investigation of students' perceptions of classroom experiences, such perceptions represent reality for the students regardless of whether they are supported by external observers.

Second, students' perceptions have repeatedly been shown to be both reliable and valid (Levy et al., 1997), comparing well with those of experienced observers (Stallings, Needels, & Stayrook, 1979). A third reason was the need for research presenting their points of view, as there is little in the literature giving students' perspectives on their subject deliberations.

Results and Discussion

The results from analyses of all three data sets are too extensive to be discussed in detail here. Rather, this report focuses primarily on the interview data concerning students' cross-referencing of the influences within their school science and family worlds, and how this process affected decisions about taking physics and chemistry. In order to understand this process, it is important to first understand how students saw these two worlds.

Students' Perceptions of School Science

There was some expectation at the outset of the project that science proficient students' decisions about whether or not to continue with further science study might be related to positive or negative experiences of school science. However, the interview respondents generally described very similar experiences and conceptions of school science, regardless of whether they were continuing with science. It was demonstrably *not* the case that the students choosing physics and chemistry courses, or indeed other science courses, described a more attractive picture of their school science experiences than did those deciding to opt out of science courses.

Four dominant themes emerged from students' descriptions of their school science experiences. First, science was seen as a teacher-centred and content-focused subject, in which facts were transmitted from expert sources to relatively passive recipients. For example:

Melinda (phys/chem/bio): The way teachers taught … it's just sort of "this is it, this is how it is, and this is what you learn." (191)

Roger (phys/chem/aviation eng.): Everyone seems to teach the same. They write it up on the board and talk to you about it … the demonstrations and stuff, it's all very similar. (549-553)

Such descriptions are consistent with findings from Australian research spanning the last decade (Goodrum, Hackling, & Rennie, 2001; Rosier & Banks, 1990). Although the majority of interview respondents were critical of this type of teaching, they generally spoke well of their science teachers. Rather, it was as if they saw the pedagogical style as a fundamental characteristic of science, with which teachers and students had to cope as best they could.

The second theme concerned the curriculum content, which was described most often as being personally irrelevant and boring. For instance:

Hannan (phys/chem): Learning about Newton's Law, (this term) … for once, science was, like, something I could apply to life. Until this year I couldn't find the link between what we learned in science and going out into the world and seeing things move and stuff. (413–415)

Richard (no science): I just found science boring, to tell you the truth. (104)

Again, similar impressions have often been reported in other Australian and international research (e.g., Goodrum et al., 2001; Osborne & Collins, 2001), and are consistent with descriptions of the prevailing pedagogy. On the other hand, the students appreciated teachers who tried to present the content in an engaging manner, although such attempts appeared to be the exception rather than the rule.

The third theme concerned the anticipated difficulty of senior physics and chemistry compared to other courses on offer. The students gained this impression both from their own experiences of physical science topics, and from comments by teachers, senior students, peers and parents. This perception often eclipsed other considerations to the extent where students discussed physics, chemistry, biology and general science courses in terms of a hierarchy of relative difficulty, rather than, say, differing content knowledge. For example:

Kelly (phys/chem): [The science coordinator] told us that physics was probably the hardest of the sciences. (89)

Phillip (bio): I like science, and biology is the easier of the sciences. 'Cause [my Dad] told me physics and chemistry are both pretty hard. (60–61)

The relative difficulty of physics and chemistry courses has been reported previously as impacting on enrolment decisions (Ainley et al., 1994; Barnes, 1999; Kelly, 1988). However, the students' narratives clearly indicated that in view of this hierarchy, self-efficacy was an important consideration. This was especially the case for girls, who tended more often to question whether they would be 'good enough' to cope with these courses. Their greater sensitivity to self-efficacy was consistent with the finding from the initial survey (Figure 4) that girls choosing physical science courses tended to rate their academic abilities in science significantly lower ($p < 0.01$, $n = 80$) than did boys choosing the same courses, despite similar levels of proficiency.

The emergence of perceived difficulty and self-efficacy as key considerations led to further exploration of these issues in the interviews, revealing a link with family relationships discussed later.

The fourth theme concerned the belief that physical science courses were primarily of strategic value, in that they would enhance the students' university and career options. The two responses below typify the students' explanations for choosing physics:

James (phys/chem): The real reason? Because most courses at uni, you need physics and chemistry. (75–78)

Sylvia (phys/chem): My science teacher said I should do physics and chemistry because it leaves a lot more doors open. (96)

This is a common perception of these courses (Barnes, 1999; Fullarton & Ainley, 2000) and one promoted strongly by universities (Fensham, 1992), though more so in the past. Indeed, over a quarter of the physical science students com-

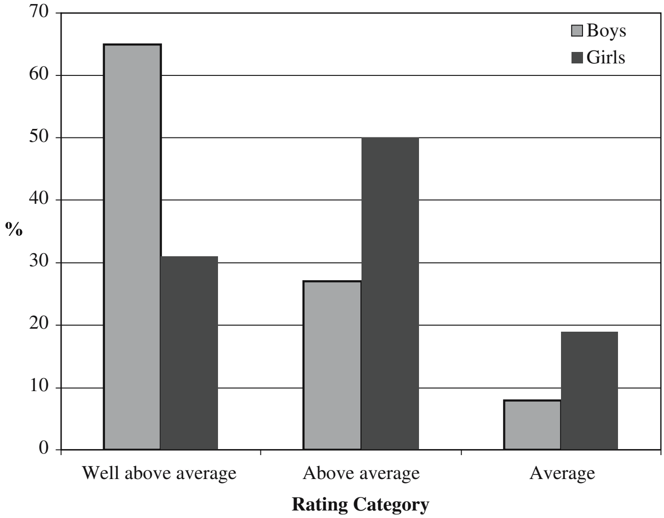

Figure 4: Self-rating of academic ability in science by boys (*n* = 38) and girls (*n* = 42) choosing physical science courses. The five point scale ranged from 'well above average' to 'well below average.' (No student choosing physical science rated his or her ability below average.)

mented that they had chosen these courses for strategic reasons despite a lack of intrinsic interest. For example:

Greta (phys/chem/bio): Well basically I need to do it [physics] because I want to do medical stuff. Basically that's the only reason I'm doing it because I *hate* physics. (320)

According to the students, the strategic value of these courses was promoted by teachers, parents and other students. The combination of difficulty and strategic value also imbued physical science courses with a certain prestige.

One aspect of this strategic motivation is often cited anecdotally as contributing to the decline in physical science enrolments. This is the contention that students today see science careers as having limited job prospects and relatively low salaries and social status (e.g., Niland, 1998). This view, echoed by 20 of the 24 teachers surveyed, was subsequently investigated in the student interviews. Surprisingly, none of the interviewees referred to such concerns in their rationales for not continuing with science study, and few were willing to even guess at the salary levels, career status or employment opportunities of scientists. Of those who ventured an opinion, nearly all anticipated that such careers would have high status and attractive salaries. Phillip's response was typical:

Phillip*(bio)*: Scientists are seen as people with a lot of responsibilities, I think, 'cause they have a lot to work on, problems to solve and stuff like that.

Res: What about their pay? Do you have any idea about that?

Phillip: Um, I'm sure that most … high … scientists, with a lot of responsibility and a lot of time to work on stuff, like biologists and stuff, would be paid a lot of money. (207–210)

The lack of support for the prevailing view is an important finding, and one deserving of further research. It may well be the case that as career directions become more important during the senior years, students develop greater awareness about issues such as pay, status and career prospects, which might then have a greater influence on their post-secondary decisions. However, for students in Year 10, findings from this study indicated that such issues have much less impact than teachers contend.

The realisation that external considerations offered less insight into students' disengagement from school science than did their uninspiring classroom experiences led to a shift in focus from the students choosing no science courses to the motivations of those who did. These motivations were generally not based on aspects of the curriculum, such as content knowledge or skills, but on what these courses were seen to represent in terms of strategic value and, in some cases, prestige. From the perspectives of students considering physical science courses, a culture already existed which presented a choice between anticipated difficulty and abstraction on the one hand, and strategic benefit on the other. Deliberations about physical science enrolment therefore involved each student referencing their sense of self-efficacy, the nature of their motivations (intrinsic/extrinsic) and orientations (present/future), and their post-school aspirations. Important insights into these qualities were found within students' descriptions of their family worlds.

Students' Perceptions of Influences Within their Family Worlds

The influence of parents on the enrolment decisions of students in this study was apparent from the initial survey data, where students ($n = 196$) were asked to rate their reliance on the subject advice of six nominated individuals. The students considered parents, and mothers in particular, to have the greatest capacity to influence their decisions, followed by peers (senior students and friends). The advice of expert, school-based, sources (science teachers and career advisors) was regarded as being the least influential. This order is generally consistent with those found in similar surveys with larger populations (Haeusler & Kay, 1997).

During the interviews, students were encouraged to talk about a range of potential influences within their families, including attitudes and values relating to school and science, and subject advice from parents or siblings. In addition to explicit references to parental influence, analysis of the narratives identified three aspects of family worlds associated with decisions about physical science courses. These were parents' attitudes to formal education, attitudes and responses to science, and the quality of students' relationships with key family members.

Parents' Attitudes to Formal Education

Eleven of the fourteen interviewees choosing physical science subjects described their parents as valuing, or in some cases embodying, the strategic importance of formal education for university or career paths. Sometimes these perceptions were based upon parents' explicit comments about schooling and achievement, but more often on implicit cues, such as their attitudes, behaviours or personal histories. For instance, just under half of the physical science students referred to a parent's regret for lost career opportunities. The contexts for this regret included parents' lack of useful qualifications, interruptions to their education or careers because of family reasons, lost opportunities due to immigration or refugee status, and dissatisfaction with employment prospects. For example:

Jennifer (phys): [Mum] missed out on going to uni herself because her mother got sick. She actually got the entrance rank high enough to get into Veterinary Science but she couldn't, so she encourages me a lot to go to university. (319)

James: (phys/chem): [Mum's] the boss at the restaurant . . . she went to school till Year 6, in Hong Kong, and she had to stop and she really regrets it. When she came over here ten years ago, it was actually quite bad in Hong Kong and people over there perceived Australia to be really lucky . . . but it was actually a hard slog to get where they are now, so that's why they urge me and my brother along. (152)

It is interesting to note that parents' regrets did not feature at all in students' initial explanations for their subject choices. However, the fact that the students referred to such regrets in further discussions about their deliberations underscored the perhaps subconscious influence of this awareness.

Parental regret was not the only context revealing a strategic orientation to education. For some students, the high status of their parents' credentials or occupations represented what could be achieved through university study. Seven students talked about parents who were currently undertaking university study, a choice signifying the high value placed on credentials. Six of the seven were physical science students, and in three of these cases, the difficulty of this undertaking underscored the importance of maximising opportunities at an early age. For example:

Greta (phys/chem/bio): I think Mum definitely regrets [leaving school early] because she can't get work anywhere 'cause she's got no qualifications for anything good . . . Now she's doing an Applied Science course at uni.

Res: Oh right. So she's going up to [city] to study? [a return journey of 200 km]

Greta: Four days a week. See, she picked the course because it's got a better employment rate than anything else. (263–265)

In contrast, students choosing not to enrol in physical science subjects more often described their parents as encouraging them to choose courses they enjoyed, or were good at, rather than basing decisions upon the strategic value of particular courses. For example:

Beth (bio): [Dad's] been saying, 'You've got to choose stuff that you like.' My Mum was saying 'It's up to you, you've got to be happy.' (76)

Mark (bio): I told (Mum and Dad) I was doing and they just said 'well if that's what you want to do, then that's what you can do – just as long as you like it, and that. (58–59)

Johnston and Spooner (1992, p. 47) refer to this as the 'as long as you're happy' syndrome, which they see as being associated with lower parental aspirations than were found among students choosing physical science subjects. However, findings from my study do not imply that the parents of biology/other science students were less involved in, or concerned about, the education of their children. Rather, these students described different parental values, which focused more on the intrinsic benefits of particular choices.

The congruence between students' descriptions of parental attitudes to education and their own intrinsic or strategic explanations for their decisions was interpreted using the framework of cultural capital (Bourdieu & Passeron, 1977). This concept has considerable merit in terms of explaining the congruence if we consider the extrinsic or intrinsic orientations of parent's attitudes to education to be different forms of cultural capital accessible to students in their deliberations. While a student is generally free to choose courses, he or she does so (often unconsciously) with reference to the available resources of family cultural capital. The usefulness of this framework for understanding the relationship between sociological influence and individual decision-making has previously been demonstrated by Hodkinson and Sparkes (1997) in the context of students' career choices.[1]

Sylvia's narrative provided an instructive example of the influence of cultural capital on science subject choice. Sylvia chose advanced mathematics and English courses, as well as physics and chemistry. While taking personal responsibility for these decisions, her awareness of the expectations of her parents, and of their high educational and professional achievements, influenced her choice of strategically useful subjects over those she enjoyed more, such as biology, art and drama:

Sylvia (phys/chem): If I'd chosen, say, Drama and Visual Arts, well ... [pause] See, my parents were very studious themselves when they were young, I know that, in the maths and sciences, they did chemistry and 3 unit maths and, yeah, I've been like that all the way through high school, and they expect me to keep on doing that. (85)

Despite her personal misgivings about taking physics, Sylvia's own orientation was consistent with her perception of her parents' attitudes:

[Drama] was enjoyable, but it just wasn't going to get me anywhere (34) ... I feel I'm a career oriented person and I feel [choosing Drama or Visual Arts] is throwing away a perfect opportunity ... I want to get good marks, a good UAI (university entrance ranking), and good experience so that I can go on, and get a career. (85)

Although the link between enrolment in physical science courses and parental emphasis on the strategic value of schooling was found in nearly all the physical science cases, it was noted that a number of students choosing no science courses also described similar parental attitudes. However, it emerged that in most of these cases the values and attitudes of the parent were not shared by the student, for reasons that are discussed later.

Family Attitudes to Science

Ten of the fourteen students choosing physical science courses described one or more key family members as strongly advocating or encouraging an interest in science. The parents of many of these students were employed in science related occupations, such as medicine, engineering or science teaching, indicating to students that science was highly valued. Other examples of advocacy included the provision of science related materials, such as books, magazines, kits and toys; frequent discussions of science-related issues; help with science projects and homework, and shared viewing of science TV documentaries. For instance:

Greg (bio): um . . . I'm not sure of the timing of this, but my Dad, my real Dad, used to buy me 'sciency' kinds of presents, things like that . . . I remember I've got some kind of a science thing and you do all experiments with weather and plants and all that kind of stuff . . . and I remember he used to get me these inventor's kits, and you could make like, rubber-band powered cars, and things like that. (234–236)

The provision of science related materials and knowledge by parents can also be seen as an endowment of cultural capital, in the sense that parents consider that these assets will enhance their child's education and, hopefully, their schooling outcomes. Likewise, parents' use of scientific discourse at home is another form of cultural capital, which, if congruent with the language and attitudes of teachers, can benefit students in their education (Bernstein, 1971).

In terms of the robustness of any relationship between cultural capital and enrolment decisions, it was recognised that four of the physical science students described family worlds in which science was not highly valued. In addition, four interviewees choosing not to enrol in science courses described families in which there was an advocate for science. In examining these discrepant cases more closely however, it was again discovered that the influence of cultural capital was mediated by the quality of students' relationships with family members. For example, in the extract above, Greg referred to his 'real Dad' as encouraging an interest in science. However, when Greg was about 11 years old, his father left the family home and moved to the UK. Greg had little contact with his father after that, and no one else in his family was an advocate for science.

Greg's enthusiasm for science waned, and he lacked the self-efficacy and interest to take physics or chemistry. This case was one of many revealing the importance of relationships with key family members to students' enrolment decisions.

Social Capital Within Family Relationships

In the course of the interviews, it became apparent that the quality of the students' relationships with key family members was a strong, if unrecognised, influence on their science enrolment decisions. The exploration of these relationships shed new light on why science proficient students who described similar parental attitudes to education, or to science, made very different decisions regarding further science study.

The quality of these relationships was gauged through students' descriptions of the support and encouragement, or 'socioemotional investment' (Bradley & Corwin, 2000) they had experienced, and the trust and respect they expressed towards key family members. According to Coleman (1988) such investment contributes towards the resources of social capital in family relationships. This extract from Daria's narrative provides an example of investment towards social capital:

Daria (no science): My brother has been playing soccer for about six years, and I used to go and watch him. I liked playing soccer and I just said to my Dad that I wanted to play, but there was no local team. (31)

... Researcher: And what did your Dad say when you said you wanted to play soccer?

Daria: Oh, he was really, ... he went and asked the club, and got them to organise and register a team and he found a coach, 'cause he was going to do it, but he just started his own business, so he couldn't. And he got my Mum to be the manager, and he helped [set it up]. (34–35)

Other indicators of relationships rich in social capital were found in the language students used when discussing family members. Intimations of respect and trust were useful in gauging the reliance which students placed on subject advice. Some students expressed this explicitly, for instance:

Roger (phys/chem/aviation eng.): I have a close relationship with my Mum, so she just helped me with everything. (229)

The study found that the quality of parent/child relationships was also implicated in the levels of confidence and academic self-efficacy of students. This was especially, though not exclusively, the case for many girls, who often referred to the encouragement and support of parents or other family members as a significant influence on their decisions to take physics and chemistry courses.

While nearly all the interview respondents described supportive relationships with mothers, one third described father/child relationships that appeared to be low in social capital. The most common descriptions concerned the lack of involvement in the student's educational or recreational activities, particularly in the ten cases in which parents were separated. Some indications were merely suggestive, for example, fathers having little interest or involvement in the process of subject choice. In other cases, however, the lack of social capital was unambiguous. For example:

Researcher: Did your father have any input into your subject choices?

Renate (phys/chem): He's in Antarctica [laughs, ironically]. He never emails us, we don't get birthday presents or Christmas presents. We have no contact with him whatsoever, really.

Researcher: So, would it have mattered whether he was in Antarctica or not?

Renate: Not really, no. I wouldn't have asked him. He doesn't really have much of an input into my life at all. (94–97)

Although Renate's father had no influence on her subject choices, her mother featured prominently in her narrative. In particular, she referred to her mother's regrets about her limited career prospects, her recent decision to enrol in a science teaching course at university, and how the quality of their relationship had given Renate the confidence to take on physics and chemistry courses.

Malcolm's narrative, which in many ways paralleled that of Greg, showed how his relationship with his father influenced his interest in science. During his pre-adolescent years, Malcolm's family world was one in which science was highly valued. Malcolm saw his father as an advocate for science, both in his career as an industrial designer and his general interests. Malcolm spoke of looking through his father's *New Scientist* magazines and the science books he'd been given, and of his interest in his father's designs for boats and airships. However, it appears that his father was the sole advocate of science within the family. His departure from the family home when Malcolm was 12 years old, as well as the subsequent physical, social and emotional distance between them, resulted in a general devaluing of science within his family. This shift clearly paralleled Malcolm's changing attitude to science, in which he regretted the loss of interest, but lacked the motivation to rekindle it:

Malcolm (no science): It's difficult with science ... I'm still very interested in it, and I used to even get *New Scientist* [magazine] and read that. I'm thinking of subscribing again, but ... um ... [long pause]. There's a possibility that ... um, no one else in my family, except my father, is really into science, and that was ... a thing there ... [voice trails off]. (230)

Malcolm: ... there was an interest [in science] that I tried to maintain.

Res: What about when you had projects or such at home? Did anyone take a particular interest in your science projects?

Malcolm: No. My mother's not much of a science person. (189–191)

Greg, Malcolm, Madeline, Tracy and Yvonne described their fathers as the sole advocates for science within their families (the fathers worked as a biologist, industrial designer, electrical engineer, metallurgist and math/science teacher respectively). In each of these cases, however, the parents were separated and relationships with fathers were low in social capital. None of these students chose physical science subjects, with Greg and Tracy choosing biology and the others taking no science courses.

Low levels of social capital also appeared to impact the self-efficacy of some students. For example, Sean's father had lived away from the family home for five years, during which time Sean lived with his mother. Despite his 'A' grade, Sean described his academic ability in science as only average. His mother had little input into his subject deliberations and he noted that his father would be unaware of his choices. Though he was in contact with his father, there was little history of help with homework or other aspects of Sean's schooling. In general his senior subject profile was not academically challenging, and had been chosen based upon intrinsic values. His reasons for not choosing science revolved around the perception that he was not good enough. Sean's manner, negative outlook and lack of involvement in sports or other interests evoked the image of a student who had low levels of self-confidence, optimism and resources of social capital.

The Interaction of Family Influences

The recognition that levels of social capital in relationships with key family members were associated with the enrolment deliberations of many of these students' helped clarify the discrepant cases mentioned earlier. Indeed, when the dimension of social capital was taken into consideration, the link between parental attitudes and students' decisions became more robust. Figure 5 represents the interactive influence of the three family characteristics discussed above. The intersection produced a number of regions, the main features of which are described below.

First, all except one[2] of the students choosing physical science courses are found within Set C, suggesting strongly that it was important for students choosing these courses to feel, either consciously or unconsciously, that they were supported by the positive relationships they enjoyed within their families. It was apparent from the interview and survey data that the majority of physical science students also possessed higher levels of self-efficacy. The narratives revealed that this quality as instrumental in students' decisions to take difficult science subjects, and rooted in indicators of social capital, such as trust and encouragement.

Second, the physical science students are situated within the intersections $A \cap C$ and $B \cap C$, with the majority located in the region $A \cap B \cap C$. That is, physical science students described family worlds in which, along with the reserves of social capital, key family members emphasised the strategic qualities of education, or provided science related cultural capital or, more trenchantly, did both. In terms of science subject choice, adequate resources of social capital in family relationships alone had little influence on the choice of physical science subjects, as shown by the 10 students in Set C only. The quality of the family relationship was effective only in influencing students to adopt the attitudes and aspirations of family members. However, for this influence to favour the choice of physics and chemistry, it was necessary for the student to perceive that the decision was consistent with the attitudes of key family members.

Third, seven students are found in A or B, but not in C. While each of these students described a parent as advocating science, or the strategic value of science

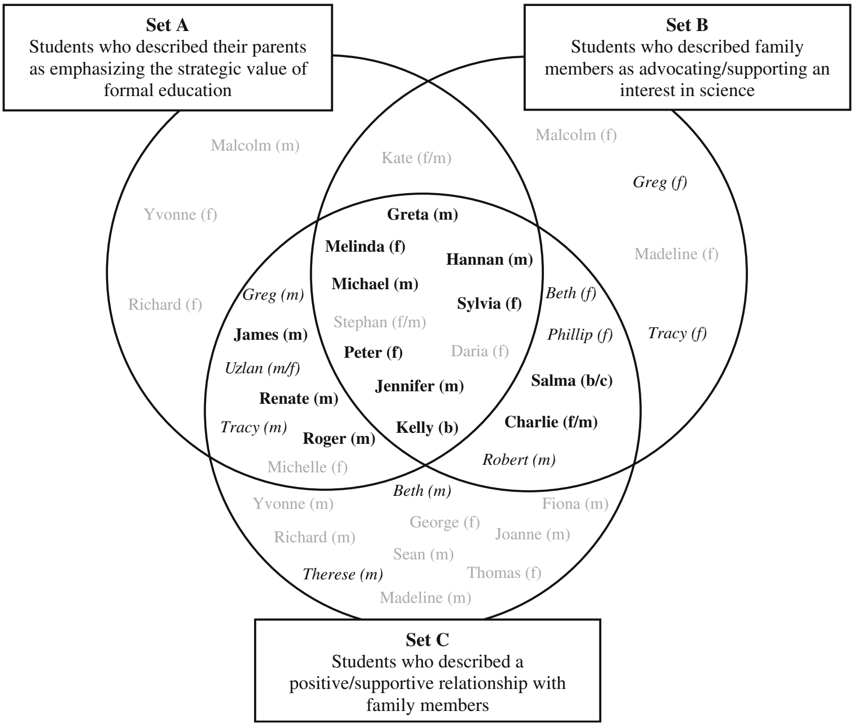

Figure 5: The interaction of three characteristics of the students' family worlds associated with their science enrolment decisions. The few cases in which attitudes or relationships described above could not be determined are not shown. Key: (*m*) mother; (*f*) father; (*b*) brother; (*s*) sister; (*c*) cousin; **Students taking physical science courses**; *students taking biology/other science courses*; students taking no science courses.

subjects, low levels of social capital in the relationship with that parent appeared to weaken the influence of any advocacy.

Putting Some Pieces Together

Congruence Between The Worlds of School Science and Family

It might reasonably be argued that family cultural and social capital could similarly influence decisions about subjects other than science. However, particular characteristics of school science, such as the chalk and talk pedagogy, the decontextualised content and the relative difficulty of physics and chemistry contributed to the perception that these subjects have less intrinsic value than most others on offer, with the possible exception of mathematics. Since the physical science students' considerations were less about interest and enjoyment, and more about what these courses represented in terms of post-school options, the impact of external considerations was greater than for other subjects. This study found the choice of biology, for example, to be associated more closely with interest and enjoyment, and less with family influences.

The evidence suggests that the students' decisions were influenced by the degree of congruence between their conceptions of school science on the one hand, and their resources of family cultural and social capital on the other. A model illustrating this congruence is shown in Figure 6. As this model is based primarily upon the deliberations of a relatively small number of science proficient students, it is offered here as a framework for future research in this area, rather than as a model applicable to larger populations.

The model implies, firstly, that science proficient students are more likely to choose physical science courses when the importance attributed to science by schools is congruent with the advocacy for science by at least one significant, and supportive, family member.

Second, enrolment in physical science subjects is more likely where the perception that they are primarily of strategic value resonates with a student's recognition that such a quality is highly valued within the family. The strategic orientation towards education of some parents is also a type of cultural capital, shown to be typical of, though not limited to, families of high socioeconomic status (Bourdieu & Passeron, 1977; Marjoribanks, 1987). This aspect of the model is consistent with the strong statistical correlations found between enrolment in the physical sciences and two important pieces of the puzzle discussed earlier, high levels of parental education and socioeconomic status.

Furthermore, the influence of cultural capital may explain an inconsistency found in the second of these correlations, whereby a disproportionate number of migrant children from low socioeconomic levels tend to choose physical science subjects. What many working class, or lower middle class migrant parents have in

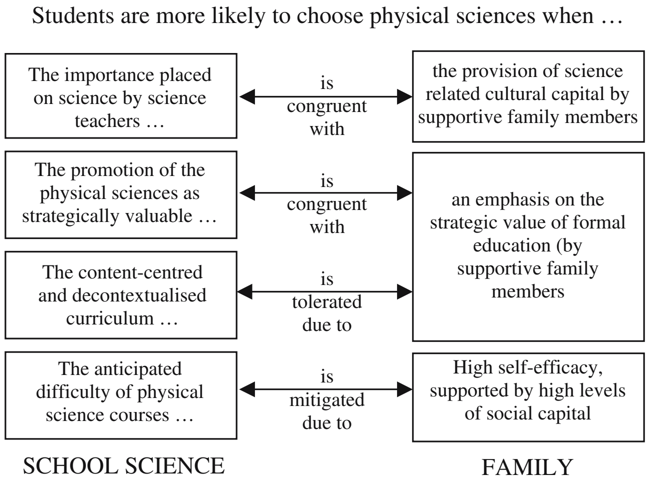

Figure 6: A model illustrating the congruence between characteristics of school science and family worlds found among the science proficient students choosing physical science subjects (Lyons, 2003).

common with non-migrant parents who have higher occupational or educational status, are high educational aspirations for their children. This is particularly the case among Chinese and Vietnamese Australian families (Mak & Chan, 1995; Ninnes, 1997). It may therefore be more meaningful to discuss enrolment patterns in these subjects in terms of differing levels and types of family cultural capital, rather than coarse demographic factors such as socioeconomic status, parents' education levels or ethnic background.

Third, students' perceptions of school science as a content-centred subject presented in a transmissive mode may resonate with parents' expectations that school education primarily involves the assimilation and recall of content. While few of the students viewed the content-centredness of school science as an attractive characteristic, the disadvantages of the pedagogical style may be offset by the strategic value offered by physics and chemistry. Likewise, it appears that students may be willing to tolerate the decontextualised and personally irrelevant content anticipated within these subjects for the benefits they offer in the long term. Such a reconciliation is consistent with the priority given by parents to strategic values over intrinsic ones.

Fourth, the difficulty of physics and chemistry courses may be less daunting for students who have higher levels of confidence, optimism and self-efficacy, qualities associated with high levels of family social capital. The quality of the parent/child relationship is particularly influential where the parent also emphasises the importance of a strategic orientation, and expresses confidence in the child's ability to take on challenging subjects.

The study found self-efficacy to be an important aspect of the gender differences in deliberation behaviour and enrolment outcomes. It may be the case that self-efficacy is simply one element of the gender puzzle which, along with social expectations (Eccles, 1989; Harding, 1996) may be more closely related to enrolment intentions than the commonly used factor, sex.

Implications for Physical Science Enrolments

Two important conclusions can be drawn from the findings above. First, the concepts of cultural and social capital offer a plausible framework for understanding the correlations between family-related factors and enrolment in physical science courses reported in previous studies. While some of these studies have implied that family attitudes, rather than material resources or ethnic identity, may be behind the correlations, there had been little evidence to support this speculation.

Second, much of the commentary on falling science enrolments has suggested that external issues, such as perceptions of the low status of science careers, or competition from newer and supposedly easier school courses, have been drawing students away from science courses (see Werry, 1998). Such a perspective assumes that enrolment in senior science courses, and the physical sciences in particular, is the default choice of any science proficient student, as has been the case in the past. This assumption has been supported by both the customary status of science in the school curriculum, and its widespread inclusion among university prerequisites (Fensham, 1992).

While external issues may have some impact, it became increasingly obvious over the course of the study that the most cogent single force acting against the choice of physical science courses was the culture of school science itself. While emphasising the status and strategic utility of physical science courses, students in this study considered school science to have fewer intrinsically satisfying characteristics than it might have. Thus, in attempting to understand the decline in physical science enrolments in Australia, it is suggested that changing external conditions, such as the decreasing strategic value of such courses as universities offer more flexible options, have only served to highlight the lack of intrinsic benefits of school science as conventionally taught. If this is indeed the case, instead of considering why clever students are no longer taking science courses, it may be more pertinent to ask, “Why should they?”

Notes

1. See also Grenfell and James (1999) for a more detailed discussion.
2. The narrative of this student did not provide enough detail about family members to draw any conclusions.

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