SEEDING SCIENCE SUCCESS: RELATIONS OF SECONDARY STUDENTS’ SCIENCE SELF-CONCEPTS AND MOTIVATION WITH ASPIRATIONS AND ACHIEVEMENT

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Statement of Authentication

The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material, either whole or in part, for a degree at this or any other institution.

W. D. Chandrasena

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ABSTRACT

In the contemporary world, every sphere of life has been revolutionised by science. As such, science understanding is an increasingly precious resource throughout the world (Aschbacher, Li, & Roth, 2010). Further, as science knowledge is contestable, continuously subject to revision, refinement, and extension (Ferrari, 2011), the dissemination and digestion of new scientific knowledge is very important.

Despite the widely recognised need for better science education, the numbers of students pursuing science continue to decline internationally, and the percentage of school students studying science is particularly low (Hannover & Kessels, 2004; Birrell, Edwards, Dobson, & Smith, 2005). Alarmingly, in Australia, the number of Year 12 students studying any science subject has plummeted from 94 per cent to just over 50 per cent in the past 20 years, and according to the available data enrolments are still falling (McDougall, 2011). This has resulted in a lack of qualified people for employment in science-related jobs. This in turn threatens our ability to continue to build an innovative economy that is competitive internationally.

Past research has shown that the decline in science enrolments is related to many interrelated factors, such as: students’ academic abilities, teaching methods, the absence of motivation to study science, and a lack of interest in science subjects (Hassan & Treagust, 2003). Students’ self-concepts, motivation, and aspirations could also be related to the decline in the number of students seeking to pursue science. However, there is a dearth of research investigating relations among students’ science self-concepts, motivation, aspirations, and achievement in different science domains. The present investigation aims to address this gap in the literature by investigating the relations among the multi-dimensional facets of secondary students’ science self-concepts, motivation, aspirations, and achievement.

Given the advantages of a mixed-methods approach (Buber, Gadner, & Richards, 2004) this research comprises three inter-related synergistic studies. Study 1 aims to develop a psychometrically sound tool to measure secondary students’ science self-concepts, motivation, and aspirations in biology, chemistry, earth and environmental
science, and physics. Study 2 aims to test the relations of multi-dimensional facets of secondary students’ science self-concepts and motivation against aspirations and achievement, across gender and age levels. Study 3 utilises a qualitative methodology to explicate students’ and teachers’ views, practices, and personal experiences, to identify the barriers to undertaking science for secondary students and to provide rich insights into the relations of secondary students’ science self-concepts and motivation with their aspirations and achievement. Study 3 will detect additional issues that may not necessarily be identifiable from the quantitative findings of Study 2.

The psychometric properties of the newly developed instrument demonstrated that students’ science self-concepts were domain specific, while science motivation and science aspirations were not. Students’ self-concepts in general science, chemistry, and physics were stronger for males than females. Students’ self-concepts in general science and biology became stronger for students in higher years of secondary schooling. Students’ science motivation did not vary across gender and year levels. Though students’ science aspirations did not vary across gender, they became stronger with age.

In general, students’ science self-concepts and science motivation were positively related to science aspirations and science achievement. Specifically, students’ year level, biology self-concept, and physics self-concept predicted their science and career aspirations. Biology self-concept predicted teacher ratings of students’ achievement, and students’ general science self-concepts predicted their achievement according to students’ ratings. Students’ year level and intrinsic motivation in science were predictors of their science aspirations, and intrinsic motivation was a greater significant predictor of students’ achievement, according to student ratings.

Based upon students’ and teachers’ perceptions, the identified barriers to promoting science in schools were: the difficulty of the subject matter, lack of student interest, the large amount of subject content, lack of perceived relevance of the subject matter to day-to-day life, ineffective teacher characteristics, lack of aspirations to pursue science as a career, inadequate teaching methods, lack of adequate teacher training, lack of proper policies to reward science teachers, and inadequate support for science from the media.
Overall, the results from this study provide a greater understanding of the relations of secondary students’ science self-concepts and motivation with aspirations and achievement in different science domains across gender and age levels. Hence, this research makes a valuable contribution to the literature by providing new insight. The findings will be useful for science educators in planning and developing science curriculum and policies with regard to student self-concepts and motivation. Equally, science teachers may find implications for classroom practices, for the planning and conducting of science lessons, for conveying scientific concepts and principles to students more effectively, and in considering the need to generate enthusiasm about the subject in young science students. Thus, the findings may offer the necessary strategies to assist in reducing the decline of students’ enrolments in science through efficacious attention to student self-concepts and motivation. The newly developed instrument provides a new opportunity for future research to confidently interrogate the psychosocial issues central to science education and promotion.
CHAPTER 1

INTRODUCTION

Science merits a place in the curriculum on the basis of its importance as part of our intellectual heritage. It is a major part of our cultural experience that should be passed on from generation to generation (DeBoer, 2000, p. 591).

The present era is the era of science. Science has been integral to improving the quality of life for humankind. Every sphere of life has been revolutionised by science. The discovery of electricity has made it possible for us to change night into day and summer into a comfortable cool season. We can now travel from one country to another country in few hours. It is now easy to cultivate fields as we have tractors. New forms of irrigation are now being employed. It is easier to protect the crops because of the use of various chemicals and pesticides. Even mosquitoes can be driven away because of the discoveries made in science. Without a computer it is impossible to prepare this type of quality document. Science has afforded us such advances.

As the pace of scientific research output accelerates, the average citizen is faced increasingly with having to grapple with science matters in everyday life. For example, behaviour is altered if people understand that smoking is a cause of lung cancer; or obesity is a cause of diabetes. The public must also grapple with important public policy questions that must be informed by science. For example, an understanding of the science of embryonic stem cell research is critically important to inform policymakers who are advocating or opposing this research; an understanding of climatology is essential to those concerned with regulation of fossil fuel consumption and energy policy; astronomy and cosmology must inform decisions about investment in space exploration.
Science is everywhere in society, a part of each person's everyday life—even grocery shopping is more informed by a basic understanding of science. But most citizens are not equipped to personally assess the facts, nor often even to separate the facts from opinion or from political spin, science from non-science. Without such capacity, they are likely to be predominantly influenced by the prevailing messages delivered in popular media or within their own communities.

No country, no matter how sophisticated technologically, can advance its society fully without the informed engagement of its citizenship. The non-scientist is increasingly at a disadvantage, because he or she lacks the information to engage in these important public policy dilemmas as an informed, independent thinker. How can we equip our people with sufficient scientific skills to enable them to develop informed opinions about these important issues, without imposing the unrealistic expectation that they be trained as scientists? Yet, without a broad populace of "science appreciators", both the continued national investment in science and the implementation of enlightened public policy will be threatened. Thus, the importance of a having an informed citizenry that understands science, and that is not confined just to the scientists and science educators of tomorrow, cannot be overstated. Further, the notion of science literacy as an important public goal needs to be addressed as a matter of urgency.

In relation to the importance of understanding science, Aschbacher, Roth, and Li (2010) state that understanding concepts and principles in science is a more and more valuable practice and experience throughout the world. Further, DeBoer (2000) states, “science classes should give students the knowledge and skills that are useful in the world of work and that will enhance their long term employment prospects in a world where science and technology play such a large role” (p. 592). According to Franklin (2013), “If you want significant facts, interesting facts, useful facts, believable facts, go to science” (p. 31). Clearly, knowledge and appreciation of science is a valuable asset to have.

In spite of the importance of science education throughout the world, the percentage of school students studying science is alarmingly low (Hannover & Kessels, 2004; Birrell, Edwards, Dobson, & Smith, 2005). There is an international decline in the number of students studying science, especially in developed countries such as the United States of America (U.S. Department of Education, 2006), the United Kingdom (Schoon, 2001), and Germany (Roeder & Gruehn, 1997). This has
resulted in a lack of available expertise to fill science positions and thus endangers economic supremacy in a competitive and rapidly-changing world.

A similar situation has been experienced in Australia during the past three decades (Wood, 2004; Hassan, 2008). McDougall (2011) reports that the number of Year 12 students studying any of the science subjects has plummeted from 94% to just over 50% in the past 20 years—and that enrolments are still falling, according to the available data. He further reports that Australia's performance in international science tests for younger teens has flatlined, with six countries—China, Finland, Hong Kong, Singapore, Japan, and Korea—now doing better than Australia—the so-called "Clever Country". It's also been revealed that in universities, only 9% of students study science. Thus, McDougall warns, Australia's prospects of making further international breakthroughs such as in cervical cancer treatment, and producing more Nobel Prize winners such as astrophysicist Brian Schmidt, will be seriously under threat.

Moreover, McDougall (2011) cites a report commissioned by Chief Scientist Ian Chubb and prepared by the Australian Academy of Science, warning that Australia has failed to engage young people in science and calls for a major injection of resources, along with greater support for science teachers. While there was a already a general appreciation that fewer students were studying physics, chemistry, and biology, the report revealed that the overall drop in science study as a whole is quite staggering. The report also reveals that students are turning off science because they believe it is irrelevant to their future careers. Further, lead author Professor Denis Goodrum claims, "In some ways we are resting on our laurels ... we are flatlining. The graph is still going down—there is no indication that it has bottomed out" (McDougall, 2011). Research astronomer Sarah Brough (2011) has urged all scientists to "get out there" and sell the subject: "It is important for scientists in any of the disciplines from maths to biology to say 'this is what I do and it's exciting’" (p. 4).

For a country that believes its future prosperity depends on innovation and on a skilled work force, this situation needs to be addressed. Smith (2011) quotes Australia’s Chief Scientist, Professor Ian Chubb on the importance of more students taking science, in order to increase the scientific literacy of the community. Professor Chubb also states that the community needs to be in a position where they are better
able to make judgements themselves, rather than being led by the loudest and most vociferous people.

The problem of declining enrolments is recognised not only by government departments and researchers, but increasingly is being reported on in the popular media. For example, *The Sydney Morning Herald* (2011, December 22, p. 12) reported that when high school students were asked why they had not chosen biology, chemistry, or physics in their senior years, many replied that they found it hard to imagine themselves as scientists, presumably wearing a white coat and huddled over test tubes in a lab. This response reveals a wide misunderstanding about the role of science education and the work of scientists.

Studying science equips students with “scientific literacy”. While it may also eventually lead to individual careers in any number of scientific disciplines, a general understanding of the scientific and technological foundations of the world we live in is just as relevant to almost any other employment, and to daily life. Thus, the reported decline in the study of the sciences at senior high school level, from 94% of students taking a science subject in 1992 to 51% in 2010, is worrisome. There are links between education and innovation and between innovation and economic prosperity. Innovation relies largely on investment in research and development. But this decline at the very early stages of science education is reverberating through the higher education sector, interrupting the path from school classroom to university lecture hall and on to industrial and university research teams. The consultancy practice Access Economics warns that Australia’s innovation and productivity goals are at risk, due to an emerging shortage of research skills (*The Sydney Morning Herald*, 2011, p. 12). Further, it argues that the answer might be found in our schools. Students say they are interested in science. However, almost 50% perceive science to be ‘hard’, 36% are bored, 25% dislike science lessons and most know little about the range of science-related jobs on offer. Thus, Australia needs to do a lot more to make science education relevant, accessible, and enjoyable.

With experts saying that urgent action is needed to boost Australia’s science and maths skills base (Jones, 2011), the federal government in Australia has increased funding to attract more university graduates in science and maths, and high school science and maths teachers. Inside and outside the classroom, scientists have a wide scope to make their profession more appealing, by highlighting not only the exciting employment opportunities but also the potential to help find solutions to
some of the world’s most pressing problems. While the carbon debate, for example, has been dominated by claims and counter claims about scientific modelling, too little discussion has been devoted to the opportunities that exist for cost-effective clean coal technology, for carbon capture and storage, for next generation low-waste nuclear reactors and for various alternatives in energy technology. Thus, in designing school science courses, national curriculum planners and education authorities need to strike a balance between factual teaching and allowing room for the more enterprising students in particular, to experiment at more advanced levels (The Australian, 2011, p. 11). Science courses must teach physics, chemistry, biology, and geology, rather than social studies, but it is also important to put those disciplines in the context of such challenges as energy production, agriculture for the developing world, space exploration, and medical research. Beyond their own teachers, students could find inspiration in world-leading Australian scientists whose contributions have enormously influenced the modern world.

Professor Ian Chubb notes that many students do not see maths and science as the “coolest subjects in the world” Hall (2012). According to Hall, one of the reasons there are not more students doing it is because they think science is boring. Science, maths, and technology need to be elevated so that people who live in this country can understand that these are critical areas for the future. Chubb considers that “The better we do it now the better our future” (p. 1). Further, teachers should make the teaching of science and maths more relevant to students’ lives, rather than overhauling the curriculum or ‘dumbing down’ the curriculum.

This burning issue of declining student enrolments in science must be addressed, to ensure that science is advanced in this country. Preparing now can save us from ‘repairing in the future’. Today’s science students are tomorrow’s inventors, medical researchers, engineers, teachers, and leaders.

Past research suggests that the decline in science enrolments is related to students’ motivation, academic abilities, and teaching methods (Hassan & Treagust, 2003). However, a comprehensive study has not been conducted to identify key psychosocial drivers and to investigate the relations between such drivers and engagement in science. This is unfortunate, as psychosocial constructs may serve as the drivers of desirable educational outcomes in science. For example, self-concept and motivation have been demonstrated by a body of international research to be key drivers. The main objectives of the present study were to capitalise on advances in
self-concept and motivation theory and research, to: (1) develop psychometrically sound measures of secondary students’ science self-concepts, motivation and aspirations; (2) investigate the relations between multi-dimensional facets of secondary students’ science self-concepts, motivation, aspirations, and achievement across gender and age levels; and (3) identify secondary students’ and teachers’ perceptions of key barriers to the uptake of science.

The research used a mixed-methods design comprising two quantitative studies and a qualitative study. Marsh, Martin, and Hau (2006) note that mixed-methods designs are useful in producing sound research findings and interpretations of component data. Further, a mixed-methods approach is most appropriate when research is intended to serve multiple audiences, such as students, teachers, and educational professionals (Mertens, 2005) as was the case for this research. More specifically, this research comprises three interrelated studies that aim to:

1. Develop a psychometrically sound tool to measure secondary students’ science self-concepts, motivation, and aspirations in biology, chemistry, earth & environmental science, and physics (Study 1);
2. Explicate the relation of multi-dimensional facets of secondary students’ science self-concepts, motivation, aspirations, and achievement across gender and age levels (Study 2); and
3. Use qualitative methodology to explicate students’ and teachers’ views, practices, and personal experiences, to identify the barriers to undertaking science for secondary students and extend the findings of the quantitative component of the investigation (Study 3).

Thus, this investigation facilitates the clarifying of these issues, offering novel and evidence-based methodological approaches to explicate the nature of science learning and teaching, in relation to the decline of student enrolments in science. Moreover, this research assists in recognising effective theoretical orientations to strengthen education, through promoting greater understanding of this key issue of declining enrolments at high school level. Hence, it contributes to elucidating the psychosocial determinants of students’ decision-making processes.

There are ten chapters in this thesis. Chapter 2 is the first of two literature reviews. Science is defined; this is followed by a discussion of the significance of
science education. Then the issue of declining student enrolments in science in developed countries such as the United States, United Kingdom, Germany, and Australia is explored further. Chapter 3, the second literature review chapter, provides explanations of the theoretical underpinnings of a range of psychological constructs used in this research, such as science self-concepts, motivation, and aspirations. Research aims, hypotheses, and research questions, along with their rationales, for each of the three studies in this research, are presented in Chapter 4. Details of the methodology employed in this research for each of the three studies are provided in Chapter 5, while the results of the three studies are presented in Chapters 6, 7, and 8. Chapter 9 presents a discussion of the research results, indicates the strengths and limitations of the research, and highlights the implications of the findings for theory, research and practice. Finally, a summary of the findings and conclusions drawn from the three studies, in relation to the research aims, is presented in Chapter 10.
CHAPTER 2

EMPIRICAL RESEARCH EXAMINING SECONDARY STUDENTS’ ENGAGEMENT WITH SCIENCE

A thorough, sophisticated literature review is the foundation and inspiration for substantial, useful research. The complex nature of education research demands such thorough, sophisticated reviews (Boot & Beile, 2005, p. 3).

Introduction
This chapter commences with a general discussion of the importance of science and science education, and provides an overview of the decline in science enrolments internationally. This is followed by a discussion of some of the issues in science education in Australia, paying special attention to declining student enrolments in secondary science. Finally, the implications of this situation for the present investigation are presented.

The Significance of Science Education
Science has been defined in many ways. For example, Shrake, Elfner, Hummon, Janson, and Free (2006) define it as a systematic method of continuing investigation, based on observation, scientific hypothesis testing, measurement, experimentation, and theory building, which leads to explanations of natural phenomena, processes, or objects, that are open to further testing, revision, and falsification. These explanations are not ‘believed in’ through faith but are accepted or rejected on the basis of scientific evidence. Ferrari (2012) notes that science has been defined as a social and cultural activity through which explanations of natural phenomena are generated. Explanations of natural phenomena may be viewed as mental constructions based on personal experiences, resulting from a range of activities
including observation, experimentation, imagination and discussion. Finally, science can be simply defined as an organised body of knowledge.

Science is critical, as it focuses on meeting basic human needs by providing the necessary knowledge and skill to advance diverse fields such as: agriculture, medicine, manufacturing industries (e.g., polymer, glass, steel, electronics, stationery, paints, dyes etc.), and transportation. Thus, advances in science impact on everybody. Hence, science understanding is an increasingly precious resource throughout the world (Aschbacher, Li, & Roth, 2010). As science underpins the development of technology, we cannot expect technology to continue to develop without science.

One of the most significant characteristics of science is the changing nature of knowledge. Science knowledge is contestable, it is forever revised, refined, and extended as new evidence arises (Ferrari, 2011).

Thus, updating and disseminating new scientific knowledge is very important throughout the world. However, despite the reformer’s vision of science education for all (American Academy for the Advancement of Science, 1990; National Research Council, 1996), many students (and their parents) consider science irrelevant to their personal interests and goals, and are unaware of how many jobs require scientific knowledge (Kadlec, Friedman, & Ott, 2007).

**Withdrawal of Students from High School Science**

**International Declines in Science Enrolments**

Aschbacher, Li, and Roth (2010) have noted that school science is often hard and discouraging; there are very few science advocates at school or home, and meaningful opportunities to work with real science professionals are scarce, even in schools with designated science or health departments. There has been a steady decline in the number of students studying science, technology, and engineering over the past decade (Birrell, Edwards, Dobson, & Smith, 2005). In addition, despite the recognised need for better science education, the numbers of students pursuing science post-schooling, continue to decline internationally. This major ‘swing away from science’ has been experienced in many countries. For instance, in the United Kingdom there is a stark decline in the number of students at the age of 16 choosing sciences such as biology, chemistry, and physics for their HSC (Higher School Certificate) level studies (Osborne, Simon & Collins, 2003).
Concerns about declines in student interest and enrolment in science courses have increasingly been expressed not only in the UK but also in Sweden, Australia, Canada, Denmark, France, Germany, India, Ireland, Japan, Korea, The Netherlands, Norway, New Zealand, and the USA (Lyons, 2006). The extent of these declines has prompted a range of international science and education bodies to acknowledge a growing disenchantment with science among young people (Drury & Allen, 2002; International Bureau for Education, 2000). Osborne, Simon, and Collins (2003) note that during the past decades there have been a number of reports, warning of declines in engagement with science in the UK and the USA. For example, such concerns have been voiced in the influential report Before it’s too late (National Commission on Mathematics and Science Teaching for the 21st Century, Glenn Commission, 2000).

Moreover, internationally, the percentage of school students specialising in natural sciences is extremely low (Hannover & Kessels, 2004). For example, Schoon (2001) found, based upon a sample of 7,649 United Kingdom students aged 16 that only 5.5% of the boys and 1.5% of the girls aspired to enter a job in the realm of natural sciences. In Germany, only about 10% of all students choose physics, and fewer than 10% choose chemistry as their major subject (Roeder & Gruehn, 1997). Furthermore, the percentage of students choosing natural sciences as a major subject has halved over the last 20 years (Zwick & Renn, 2000). A similar development in the UK is documented in The Report of Sir Gareth Roberts’ Review, (2002). Other studies have shown that when asked to rank school subjects according to personal preference, typically, language subjects are at the head of the list, while the sciences are at the far end (Sullwold, 1989; Zwick & Renn, 2000). Staples (2006) has also lamented that large numbers of aspiring science majors, perhaps as many as half, become discouraged and migrate to other disciplines before graduating.

In the USA, females and most minority groups continue to be under-represented in the physical sciences (studies related to chemistry, physics, and other related subjects), engineering, and technology (National Science Board, 2006; National Science Foundation, 2006; U.S. Department of Education, 2006). Asbacher et al. (2010) point out that engaging more students in learning science, particularly under-represented females and minority groups, could not only increase the talent pool but also lead to more equitable economic opportunities, wider utilization of science understandings in people’s lives, and new viewpoints in the practice and
teaching of science. This is a dire concern, as world-class competence in science subject domains is essential to compete successfully in today’s global marketplace. Accordingly, successful careers are found more and more often in the realms of technology and natural sciences (Hannover & Kessels, 2004). Asbacher et al. (2010) also state that newcomers to the discipline could influence the goals, knowledge, and culture of science. Thus, the inclusion of diverse populations in the field of science has dual benefits – those for the individuals pursuing science and for science itself.

As science education efforts fail to reach out and invite all students to learn science, the current workforce ages, and fewer American science and engineering graduates enter the labour force. Concerns have grown about the USA’s ability to remain globally competitive, to retain good jobs, and a high standard of living (Business Roundtable, 2005; National Academies, 2007).

The History of Science Education and its Decline in Australia

The Australian school science education system. Dekkers and Laeter (2001) state that in Australia science education has evolved within the context of the prevailing science and technology policies of both the Federal and State governments. Education is primarily the responsibility of the six States and two Territories, which comprise the Commonwealth of Australia. The States and Territories, historically, have protected their independence in educational matters, and traditionally they have opposed any attempt at Federal intervention. However, in the last decade a national approach has been taken with respect to school curriculum issues, and a national curriculum has been planned by the present Federal government, to be introduced in the next couple of years.

Dekkers and Laeter (2001) report that, in relation to science and technology policy there is essentially a unanimous acceptance, at both State and Federal levels, of the importance of science education. There is also recognition of the need to attract a cadre of good science teachers into the teaching profession if Australia is to achieve its goals for the future. This is due, at least in part, to the recognition by successive Federal Governments that Australia’s future as a developed country will increasingly depend on its ability to compete in a competitive, technological world.

The scientific community in Australia has made a number of significant contributions to science education at both the primary and secondary school levels, to ensure that science education features prominently in schooling and that curricula are
appropriate and relevant (Dekkers & Laeter, 2001). Much of this has been achieved through the Australian Academy of Science (AAS), which has produced a series of textbooks at both the secondary and, more recently, at the primary level, to provide up-to-date and educationally sound science education materials to the school system. The AAS has also been a powerful voice in the political arena, reminding governments of the importance of a sound science education system to the future economic prosperity of the country.

Until the 1960s the major goal of science education in Australia was to provide a sound basis for future professionals in engineering, science, and related fields. At a time when only about a third of the age cohort completed secondary education, the science education programme was elitist and disciplinary-based. It was also dominated by a Public Examination system that provided entry to university education through a matriculation process. Since that time, another major goal of science education has emerged, namely: to provide the opportunity for all students to achieve a measure of scientific literacy and an understanding of science and its relevance to society (Jenkins, 1994; Millar, 1996; Fensham, 1997). This latter goal has assumed a much higher standing in Australia over the past 20 years, as a greater proportion of the age cohort complete secondary education to Year 12, and the importance of science in the Australian social fabric has been increasingly recognised.

**Primary school science.** Prior to 1990, the provision of science education at the primary level was, for the most part, uncoordinated and haphazard. The Discipline Review of Teacher Education in Mathematics and Science stated that the teaching of primary school science was ‘in a state of crisis’ (Speedy, 1989). This view was shared by other observers of science education in Australia (e.g. Dekkers, Laeter, & Malone, 1991). Primary school science was usually of the ‘nature study’ variety, and what was taught was usually left to individual schools or teachers to decide. Most primary schoolteachers lacked confidence and competence to teach a comprehensive science programme (Yates & Goodrum, 1990; Australian Science Technology and Engineering Council [ASTEC], 1997). This was largely due to the omission of an in-depth coverage of science in pre-service education. In addition, the majority of students in university courses had studied little science at the senior secondary level, thus further undermining their confidence to teach science to their future students. The introduction of science as one of the eight Key Learning Areas
(Hobart Declaration on Schooling, 1989) in primary schools provided an important impetus, and the AAS launched a major national initiative to introduce science, technology, and environmental studies teaching materials into primary schools. This initiative led to the curriculum project ‘Primary Investigations’ (AAS, 1994). One of the main goals of this project was to sustain children’s natural curiosity by encouraging them to explore their surroundings and improve their understanding of the natural world. In some states over 50% of schools adopted the ‘Primary Investigations’ curriculum (ASTEC, 1997). The Commonwealth Government also instituted a National Professional Development Programme, designed to provide professional development for all teachers. Some of these funds were used to enable primary teachers to teach the new curriculum materials with skill and confidence.

A further issue concerning the teaching of science in primary schools is that of the professional development of teachers. It is apparent that primary teachers have not been emerging from tertiary education programmes with an adequate knowledge base in science to teach primary science with confidence. This issue should, in ASTEC’s opinion, be addressed by the Council of Education Deans of Australian Universities (ASTEC 1997). However, as a majority of primary teachers spend a lengthy period in their profession, a more pressing issue is to provide professional development opportunities for practising teachers. ASTEC has recommended that the Commonwealth should provide matching funds for appropriate in-service education in science and technology. The ASTEC study also revealed a high level of agreement on the outcomes expected by principals, teachers, and parents who participated in this study. At present, K-6 school children are offered science and technology subjects that were last reviewed in 2008.

**Secondary school science.** Science is a component in the compulsory years of secondary schooling, and is taught as a unified subject embracing the various sciences from Year 7 to Year 10. However, at the upper secondary school level (Years 11-12), the study of science is not compulsory. The science subjects offered are: biology, chemistry, physics, earth & environmental science, and senior science.

**Declines in science enrolments in Australia.** The number of students taking science in Year 11 and 12 in Australia has been falling steadily since 1976, and the proportion doing physics has almost halved (Wood, 2004; Hassan, 2008). Thus, it is apparent that many students are moving away from science. The three discipline-oriented Public Examination subjects (Biology, Chemistry, and Physics) reached a
peak in popularity in 1992, but then suffered a decline in enrolments. In 1998, the
difference between the total Year 12 cohort and the total number of Year 12 science
enrolments was approximately 29,000 (Dekkers & Laeter, 2001). In that same year,
26% of the Year 12 student cohort enrolled in Biology, 20% in Chemistry, 18% in
Physics, and 13% in Alternative Science. Whilst some initiatives in science
education have occurred in Australia over the past two decades (e.g., Production of a
series of text books at both the secondary, and more recently at the primary level, to
provide up-to-date and educationally sound science education materials to the school
system), the net result is still a smaller proportion of students studying science
subjects at Year 12 since 1989; and the proportion has continued to diminish each
year since then.

Jones and Young (1995) surveyed students undertaking public education in
New South Wales. This was a longitudinal survey spanning three years, which
examined students from schools mostly in Sydney and Wollongong. Fourteen high
schools were included in this purposive sample. The sample consisted of 962
students in Year 7, 1,107 students in Year 8, and 1,173 students in Year 9. They
found very low retention rates in science areas, and also reported that many students
did not perform well in science.

The AAS (2011) have emphasised that senior high school students have
abandoned science in “staggering” numbers and that the downward trend is likely to
continue (also see Smith, 2011; Ferrari, 2011). The percentage of Year 12 students
taking science had peaked at 94% in 1992 and was 51% in 2010. Furthermore,
student participation in science from 1991 to 2002 evidenced a sudden fall of almost
40,000 students between 2001 and 2002 (Ferrari, 2011). In Australia, the proportion
of Year 12 students taking physics has fallen 32% between 1992 and 2009. The
decline for biology was the same, while chemistry was down 25% (Lane & Puddy,
2012). Thus, Lane and Puddy advocate that there is a need to increase the demand by
making these subjects so compellingly interesting that students will want to do them.

This decline in science enrolments has important implications. For example,
though 4,500 agricultural jobs were advertised in 2010, Australia has produced only
743 graduates in agricultural science. Werner (2012) reports that The Dean of
Science at the University of New South Wales has said more people need to be
trained in science. McDougall and Jones (2011) have concluded that Australia is in
danger of losing its mantle as a world leader in education and innovation, as
educators are struggling to entice enough students to study science and mathematics. Academics believe the nation will suffer a significant expertise shortage in coming decades-undermining the push to be a “Clever Country”. For example, only 9% of Australian university students are enrolled in science and maths degrees, compared with 26% in South-East Asia. Barry Jones, a former science minister in the Hawke government, has noted that the deficiency starts in primary schools, where a high proportion of teachers are themselves uneasy with maths and science; by high school, students move to other interests. The AAS, in consequence, has urged the government to do more to support enrolments in science and mathematics and to enhance in-service teacher education.

Declines and issues in relation to science achievement. The administration of standard assessments across countries provides an opportunity to monitor the performance of Australian science students within the international context. Alarmingly, Australia’s performance has remained steady while other countries, such as Singapore and China, have improved since 2000. For example the PISA (Programme for International Student Assessment; 2009) results, published by the Organization for Economic Co-operation and Development (OECD) reveal that Australia is behind: Shanghai-China, Finland, Hong-Kong China, Singapore, Japan, Korea, New Zealand, Canada, and Estonia in student performance in science. A report by the AAS (2011) on the status and quality of Year 11 and 12 science in Australian Schools in 2011 concluded that part of the problem was that the science curriculum has become overcrowded with content. This situation encourages teachers to make students memorise lots of facts and figures, rather than to study concepts in depth, this could be uninspiring both for teachers and students. According to Ferrari (2011), part of the problem is that students and teachers believe science courses in Years 11 and 12 are constructed only for those intending to study the discipline at university, and some students are advised by their schools not to take the subject, so as to maximise their marks. Students have been encouraged to study other subjects that are considered to be easier, with the aim of maximising their final university entrance results by dropping the science subjects, due to their perceived difficulty. According to Ferrari, although 75% of non-science students agree that science is important to Australia’s future, only a very few consider that science is important, relevant, or useful in their own everyday lives. Dayton (2012), based on a survey of Year 11 and 12 students reports that only 4% of the students thought
science was “almost always” useful in everyday life, while 60% thought it was “never” or only “sometimes” useful. Only 1% thought science was “almost always” relevant to their future, while 42% thought it was “never” relevant. Clearly there is a need to make the teaching of science more interesting and relevant. The content-laden curriculum encourages science in Years 11 and 12 to be taught in a traditional way, using the transmission model, which assumes that students know little and that the role of the teacher is to fill their heads with new facts and knowledge.

Australian Nobel Prize winner Brian Schmidt warns that Australia risks being left behind in the Asian Century if we do not take science and innovation more seriously; Australians need to elevate teaching and to see science as a worthy career path (Megalogenis, 2012). While Australia boasts world-class university research, it is below average on the matter that drives growth—innovation (Megalogenis 2012). Thus, Schmidt has expressed the view that Australia must correct its poor record of translating basic research into products and other forms of innovation that help improve living standards.

Public awareness of the issue of science literacy has reached the point where politicians are also raising related issues on the need and importance of science. According to Shadow Federal education spokesman Christopher Pyne, if Australia wants to succeed economically, schools must teach the basics of science properly, along with the other subjects, furnishing advanced knowledge and concepts in preparation for university. Clearly, curriculum quality and teaching standards are two main keys to success. A well-targeted investment of resources is also important, but extra funding alone will not resolve the issue. Education authorities and curriculum planners need to be selective about how resources are spent and, especially, what is taught: both in school classrooms and in university courses. If Australia is to succeed economically, schools must teach the “basics” of science and other rigorous subjects, as well as advanced knowledge and concepts in preparation for university. It has been emphasised that quality teachers make all the difference (The Australian, 2012, February 10, p. 13).

As Dayton (2012) reports, chief scientist Ian Chubb, is concerned with the growing anti-science culture that denigrates science and scientists, to the detriment of Australia’s national interest. If left unchecked, this anti-science culture could have a negative impact on innovation, education, and economic wellbeing, and could deter
young people from choosing to study science or to follow a scientific career, since high school students are shunning science courses, viewing them as irrelevant.

The Gonski Report (Review of funding for schools, 2011) emphasised the role of teachers, stressing that high quality teaching is essential to raising educational outcomes. In addition, in Australia, as in many other countries, there is a shortage of qualified science teachers, and the scientific literacy of the population is below an adequate standard (Australian Council of Deans of Science, 2003). Considering reforms proposed by the New South Wales (NSW) government, Ferrari (2012) reports that aspiring teachers will have to study science at school, and meet minimum entry scores to qualify for a limited number of places in education degrees at university. Ferrari (2012) further reports that there is a need for minimum standards to qualify for teaching, including prerequisite secondary study of maths, science, and/or a language as well as English, and an assessment process to ascertain applicants’ suitability for and commitment to teaching.

According to Lyons (2006), many students experience a tension between the strategic benefits anticipated from enrolment in senior science courses and the disadvantages of further engagement with a subject that provides little intrinsic satisfaction. The importance of investigating students’ attitudes towards studying science has been emphasised by the mounting evidence of a decline in the interest of young people in pursuing scientific careers (Smithers & Robinson, 1988). Osborne et al. (2003) state that, taken together with research indicating widespread scientific ignorance in the general populace, and an increasing recognition of the importance and economic utility of scientific knowledge and its cultural significance, the falling numbers choosing to pursue the study of science has become a matter of considerable societal concern and debate (e.g., House of Lords, 2000). Consequently, the need for greater promotion of favourable attitudes towards science, scientists and the learning of science, which has always been a component of science education, is increasingly a matter of concern.

One of the long-term effects of the decline in the numbers of students learning science is the lack of qualified people to undertake responsibilities in science-related employment in the future. Contractor (2004) has concluded that Australia needs an extra 75,000 scientists in the fields of chemistry, physics, and mathematics within the next six years. Similarly, a number of recent media articles have forecast potential shortages in science graduates (e.g., Price, 2007). The
Australian Prime Minister, Julia Gillard (2010), addressing the nation’s most eminent scientists gathered for a presentation of the Prime Minister’s Prizes for Science indicated that “Scientists are needed more than ever”. Gillard’s insistence on the need for an increasingly scientifically-engaged outlook in Australia, together with the looming shortages, paints a gloomy scenario.

There is also a growing concern that the reduction of enrolments in science and technology subjects in Australia is threatening the success of the country’s innovation economy. For example, a decline in the study of basic sciences is predicted to affect Australia’s high technology economic sectors. Moreover, quite outside of the economic considerations, the decline of interest in science is a serious matter for any society trying to raise the level of its scientific literacy (Osborne, Simon, & Collins, 2003).

**Implications for the Present Investigation**

Scientific knowledge has revolutionised human life and led to the raising of living standards. Thus, understanding at least basic concepts and principles of science is very important to everybody in this world. However, declining student enrolments in science in developed countries will not only result in a lack of qualified people for science-related occupations, but also threatens the future of efforts to continue and sustain the building of competitive, innovative economies in the international market.

However, no comprehensive study has been conducted into different disciplines of science, such as biology, chemistry, physics, earth and environmental science in Australia, to elucidate whether psychosocial constructs (e.g., self-concepts, motivation) may hold the key to future success, and to further explicate what is underpinning the crisis of student enrolments in science. Thus, the prevailing situation in Australia and other countries has provided the catalyst for this study to contribute to addressing this critical issue by investigating and further exploring the issue, to gain deeper, fruitful insights into the problem.

Over the last decades, researchers from many different disciplines (e.g., psychology, education science, didactics for physics, and chemistry) have been trying to identify the factors that contribute to students’ reluctance to enter the science field, with the aim of reducing barriers to approaching the corresponding occupations (Hannover & Kessels, 2004). Some research has shown that the decline in science enrolments is related to interrelated factors, such as: students’ academic
abilities, teaching methods, the absence of motivation to study science, and a lack of interest in science subjects (Hassan & Treagust, 2003).

A body of research has also shown that higher levels of self-concept in specific domains are linked to various educational outcomes, such as educational aspirations (e.g., Marsh, 1990a; Marsh & Craven, 1997; 2006; Marsh & Hau, 2003). In addition, self-concept has been found to share a dynamic and mutually reinforcing causal relation with achievement (Marsh & Craven, 1997; 2006). Motivation too is demonstrated to be important for effective learning (e.g., Martin, 2003). For example, Pintrich (2003) has reported that better motivated students perform better on school grades and other achievement outcomes. According to Lyons (2006), many students experience a tension between the strategic benefits anticipated from enrolment in senior science courses and the disadvantages of further engagement with a subject that provides little intrinsic satisfaction. Hence, the presence of tension discussed by Lyons suggests that students’ science self-concepts, motivation, and aspirations could be related to the demise in the number of students seeking to pursue science as a career. Given the interrelatedness of these three constructs and the dearth of research investigating relations between students’ science self-concept, motivation, aspirations, and achievement especially in different science domains (Chandrasena, Craven, Tracey, & Dillon, 2011; 2012) they should be investigated when seeking to understand why there is a decline in the number of students taking science. The This is a significant gap in our knowledge, as little is known about how students’ science self-concepts and motivation may vary in different domains of science (e.g., physics, chemistry), and whether multiple dimensions of science self-concept and motivation vary as a function of age and gender which could affect the demise in the number of students pursuing science.

The present investigation aims to address this gap in the literature by investigating the relations among multi-dimensional facets of secondary students’ science self-concept, motivation, aspirations, and achievement. The study’s purpose was to develop and test psychometrically sound multi-dimensional science self-concept and motivation measurement tools, to afford a greater understanding of the nature and relations of the key constructs under investigation, of the key drivers of science achievement, and the perceived barriers to undertaking high school science.
Chapter Summary

This chapter has presented some definitions of science and underlined the importance of science for today and the future. The observed decline of student enrolments in science has been discussed in both international and Australian contexts, in the context of the need to empower students with scientific concepts and principles. Whilst various research has investigate the factors contributing to this decline in student enrolments in science, a comprehensive investigation of key psychosocial constructs in different disciplines of science such as biology, chemistry, physics, earth and environmental science, has not been conducted. Thus, this study seeks to identify the drivers for seeding success in science, and the barriers to studying science in different disciplines, to understand the factors underpinning declining student science enrolments. The theoretical underpinnings and significance of students’ science self-concepts, motivation, and aspirations, are explored in the next chapter.
CHAPTER 3

THE SIGNIFICANCE OF SCIENCE SELF CONCEPTS AND MOTIVATION FOR SCIENCE ASPIRATIONS AND ACHIEVEMENT

The literature review is integral to the success of academic research (Hart, 1998, p. 13).

Introduction

In this chapter, a set of psychological variables such as students’ self-concepts and motivation are hypothesised as factors that may influence students’ science aspirations and achievement, and how students respond when deciding whether or not to continue pursuing science, whether at school, or after leaving school. Psychological variables are known as constructs, or latent variables. According to Strauss and Smith (2009), a construct is a psychological process or characteristic believed to account for individual or group differences in behaviour. As with non-latent variables (commonly referred to as observed or manifest variables), the ability to quantify them accurately is important in scientific research. However, as constructs are not directly observable, they are difficult to measure. Given their abstract nature, the importance of theory in measuring constructs cannot be overstated (Netemeyer, Beardon, & Sharma, 2003). Thus, this chapter starts with a discussion of theory in measuring constructs, followed by a discussion of the constructs employed in this research. These constructs include self-concepts, motivation, and aspirations. For each of these constructs, first the theoretical background is discussed, followed by a discussion on the specific constructs used for the present study: students’ science self-concepts, science motivation, and science aspirations. Finally, the implications for the present investigation are discussed.
Theoretical Concepts and Constructs

Overview

Philosophers, scientists, and those who are curious about human nature have long observed that humans act in ways that, while they may appear highly individualistic, are in reality often characterised by consistency or predictability (Marsh, Relich & Smith, 1983). Given this fact, the study of constructs was introduced with the aim of better understanding human behaviour. In the social sciences, a psychological construct is a complex idea that we form in order to summarise observations, where these observations are assumed to be caused by that underlying construct. Though we can visualize concrete objects such as a computer and a book (and readily quantify them), many common human traits or characteristics are not so easily conceived of. For example, it is very difficult to directly visualise ‘self-concept’, ‘motivation’, and ‘aspirations’, even though people typically have intuitive ideas of what they are. In the social sciences these ideas that are not immediately measurable are often addressed by describing specific observable attributes that, taken together, define a construct. Thus, by measuring these defined qualities the psychological constructs can also be defined and measured.

Cote, Buckley, and Best (1987) describe constructs as intangible or non-concrete characteristics or qualities on which individuals differ. Constructs are also defined as informed, scientific ideas developed or hypothesized to describe or explain behaviours (Cohen & Swerdlik, 2010). Morse, Hupcey, Mitcham, and Lenz (1996) describe constructs as tools used for the purpose of organising reality. Hence, a construct is hypothetical, and not real: just as a clock may represent the time, it is not time itself, but rather, reflects the existence of time. As Netemeyer, Beardon, and Sharma (2003) note, due to their latent nature, the constructs we focus on represent abstractions that can be assessed only indirectly.

Ultimately the validity of any scientific research is a theoretical consideration, insofar as it is affected by understandings of the related constructs. However, scientific method is often neglected in the process of clarifying and conceptualising constructs (Machado & Silva, 2007). Marsh and Yeung (1997) point out that though sophisticated software packages and advanced statistical techniques are available for research, this is still no guarantee of valid conclusions (Marsh & Yeung, 1997). Thus, the conceptualisation of constructs needs to be given adequate
consideration, in order to assure the validity of the conclusions derived from the research.

**Conceptualising a Construct**

Constructs themselves are not directly observed, but are “ultimately derived from empirically observed behavioural consistencies” (Anastasi, 1986, p. 5). Constructs should have a relation with observed behaviours (DeVellis, 2003). “Behaviour” in this sense means observable actions such as responses to test or survey items, or any physical action.

While it is important to define a construct of interest carefully, Bryant (2000) suggests that researchers should provide conceptual definitions before providing operational definitions. Such conceptual understanding and definition of the construct of interest helps the researcher understand its purpose and usefulness or application. Once conceptualised, the construct potentially will have many different operational definitions (Leary, 2004). For example, the construct of self-concept may be defined in different ways through the different expertise of psychologists, sociologists, and educators. This is dependent on the respective operational definitions that meet their particular research needs. Hence, researchers need to select or develop operational definitions that suit their purposes. However, it is anticipated that the different definitions nonetheless describe a common construct. Different definitions will highlight different facets, according to the research context. One particular definition is not necessarily more correct than any other, but rather, is better suited to a particular context or is more useful than another in helping the researcher to achieve his or her research goals.

**Construct Validity**

Typically, constructs are quantified using surveys that have undergone psychometric evaluation. Construct validation is the process used to determine whether survey instruments actually measure what they are supposed to measure. Thus, construct validity refers to whether or not a scale or test measures the construct adequately. Reber (1985) states that construct validity concerns a set of procedures for evaluating the validity of a testing instrument, based on a determination of the degree to which the test items capture the hypothetical quality or trait (i.e., construct) they were designed to measure.
According to Cronbach and Meehl (1995), construct validity is the extent to which a measure “behaves” the way that the construct it purports to measure should behave, similar to established measures of other constructs. For example, based on the theory where a variable is hypothesized to be positively related to constructs P and Q, negatively related to R and S, and unrelated to X and Y, a scale that seeks to measure that construct should demonstrate relations that accord with those hypotheses. Indeed, Kaplan and Saccuzzo (2005) define construct validity as the degree of agreement between a score derived from the instrument and the construct it is supposed to be measuring.

Kline (2005) states that survey instruments designed to measure a construct are neither valid nor invalid in and of themselves. Hence, the scores obtained from a survey instrument are also neither valid nor invalid in and of themselves. Although judgements of the reliability of a survey instrument for a sample may be made through statistical measures such as Cronbach’s alpha, there are no such direct statistical measures to make judgements on the construct validity of a survey instrument. Instead, judgements on the construct validity of an instrument are based on the appropriateness of the inferences derived from instrument test scores where the inferences are guided implicitly or explicitly by theory (Cohen & Swerdlik, 2010; Furr & Bacharach, 2008; Thompson & Daniel, 1996). That is, if theory (which relates to the conceptualisation process) dictates that people rated high on a particular construct will behave in a certain way, while people rated low on the construct will behave in a different way, then the construct validation process should confirm this. As Byrne (1984) states, “construct validation studies seek empirical evidence to support hypothesized relationships associated with the nomological network of a construct” (p. 431). Hence, construct validation should be undertaken in reference to at least one other construct or observable behaviour. For example, in assessing the construct validity of a survey instrument that purports to measure ‘anger’, the assessment should seek to determine whether people who score high on the anger scale, behave in ways predicted by a relevant theory that describes anger.
Establishing the Validity of a Measure in a Different Context
A survey instrument that is shown to be valid for one purpose is not necessarily valid for another purpose (Carmines & Zeller, 1979; Hunsley, Lee, & Wood, 2004). Thus, validity is a matter of judgement that pertains to test scores as they are employed for a given purpose and in a given context (Urbina, 2004). Due to the complex nature of the procedures, it is difficult to devise statistical methods to test construct validity. Thus, establishing good construct validity is a matter of experience and good judgement of the supporting evidence.

It is important to use the same definition for a construct in different studies, in order to make meaningful comparisons. Though existing validated instruments may be available, it may be necessary to develop a new instrument (or modify an existing one) if the aims and objectives of the investigation of the new study vary significantly from the types of study for which the original survey instrument was employed. Due to the nature of context dependency (Urbina, 2004) and the purpose-specific nature of constructs (Whitely, 2002) it is not always appropriate to assume that the validity of an instrument carries from one context to another. Hence, it is desirable to test and confirm validity in new contexts, even with the use of well-established scales (Hair, Black, Babib, Anderson, & Tatham, 2006). Rust and Golombok (2009) suggest that the construct validation process is “never complete, but is cumulative over the number of studies available” (p. 81). Hence, construct validity cannot be established by one final test or operation, but is supported by the gathering of ongoing evidence. For this reason, claims relating to the validity of survey instruments are assumed to be open to modification and ongoing verification.

Having described the nature of constructs and their uses, the main constructs to be utilised in this research are discussed next. These constructs are: self-concept, motivation, and aspirations.

The Significance of the Self-Concept Construct
As individuals mature, the emergence of new cognitive capacities allows adolescents’ self-conceptions to become increasingly more abstract. In fact, various researchers (e.g., Byrne & Shavelson, 1996; Harter, 1999; Marsh, 1989) contend that self-conceptions tend to become more differentiated, complex, and better organised as individuals progress from childhood to adulthood. This observed developmental trend is good reason to suggest that our understanding of academic achievement and
well-being will be further enhanced by giving consideration to self-concept. For this reason, research into self-concept has attracted considerable attention over the past few decades.

**Theoretical Models of the Self-Concept Construct**

**Overview**

This section provides an overview of theoretical conceptualisations and different models of the self-concept construct. The following paragraphs discuss the theoretical background of the self-concept construct as it relates to the present investigation.

**The Self**

The concept of self has been studied extensively by philosophers and psychologists, and is central to many world religions. The philosophy of self seeks to describe essential qualities that constitute a person's uniqueness or essential being. There have been various approaches to defining these qualities. The self can be considered as that being which is the source of consciousness, as the agent responsible for an individual's thoughts and actions, and/or as the substantial nature of a person which endures and unifies consciousness over time. Bracken (1996) has stated, “Because the self is not an observable phenomenon, one can only make inferences about self-related constructs by observing and making inferences about an individual’s behaviour” (p. 465). As “self” is itself a construct, the characteristics of constructs described earlier in this chapter are readily applicable here: in particular, the self is not easily described by a universal definition, nor is it easily measured or quantified.

**Defining and Conceptualising Self-Concept**

While Bracken (1996, p. 465) conceptualises the self as the “essence of the individual”, many researchers have not provided a theoretical definition of self-concept (Marsh & Craven, 1997). Given that it is a hypothetical construct, Butler and Gasson (2005) suggest that it is not surprising that a universal definition is lacking. However, an examination of some of the available definitions can help provide an insight into this central construct of psychology. Stets and Burke (2005) define self-concept as the set of meanings we have of ourselves, based on our own observations, as well as inferences about who we are, based on others’ behaviour toward us.
Hamachek (1987) explains the self-concept as the cluster of ideas and attitudes we have about our awareness at any given moment. Shavelson, Hubner, and Stanton (1976, p. 407) have defined self-concept concisely as “a person’s perception of himself formed through his experience with his environment”.

As Burns (1979) notes, self-concept is a construct, as it is not directly observable. Yet constructs can be used to measure human self-concepts, as humans have the ability to reflect back on themselves as objects (Stets & Burke, 2005). However, self-concept measures can be inaccurate, due to the respondent’s tendency sometimes to systematically distort (whether consciously or unconsciously) his or her responses (Piedmont, McCrae, Riemann, & Angleitner, 2000). For example, the tendency for people to give socially desirable responses deserves consideration when conducting research, since such responses have potential to affect the measurement of the construct, as well as its relations with other constructs (Netemeyer et al., 2003).

Early research conceived of self-concept as a unidimensional construct emphasising a single, global measure of self-concept (Byrne, 1984; Wylie, 1979). The usefulness of unidimensional perspectives has since been strongly criticised (Marsh & Craven, 2006; Wylie, 1979). Whereas early research studied global self-concept, recent studies have begun to shift the focus to the measurement of multiple facets of self-concept. Shavelson, Hubner, and Stanton (1976) developed a theoretical model of a multidimensional, hierarchical self-concept in which general self appears at the apex and is divided into academic and non-academic components, which are further divided into more specific components. Subsequent research (Marsh, Byrne, & Shavelson, 1988; Marsh & Craven, 1997; 2006) has been very important in demonstrating the existence of separate dimensions of self-concept, as demonstrating the increasing differentiation and complexity of self-concept with age (Marsh, 1989).

Having discussed the nature of self-concept above, different theoretical models of self-concept, such as the unidimensional model, the multidimensional model, the internal/external frame-of-reference model, and the reciprocal effects model are explained in the following sections.

**Unidimensional models.** Similarly to Spearman’s model (Spearman, 1927) of intelligence, a unidimensional model of self-concept suggests that there is only a general factor of self-concept, or that a general factor dominates more specific
factors. For example, historically, Coopersmith (1967) and Marx and Winne (1978) have argued that the facets of self-concept are so heavily dominated by a general factor that they could not be adequately differentiated. However, the conclusions of these studies have been largely discredited and it has been revealed that they may reflect problems in measurement approaches and statistical analyses (see review by Marsh & Hattie, 1996).

Early research also highlighted the limitations of the self-concept instruments used at that time. Shavelson et al. (1976) found only modest support for the separation of self-concept into social, physical, and academic domains, and no one instrument was able to differentiate reliably among even these broad self-concept domains. Subsequently, multi-trait-multi-method (MTMM) research based on psychometrically stronger instruments (e.g., Marsh, 1990b, 1993a; Marsh, Byrne, & Shavelson, 1988; Marsh & McDonald-Holmes, 1990; Marsh & Richards, 1988b) demonstrated strong support for the convergent and discriminant validity of multidimensional self-concept responses from different instruments. Interestingly, Marsh (1992) has shown that self-concepts in specific school subjects are much more differentiated than the corresponding school grades in the same subjects. Thus, it has come to be accepted that the unidimensional model of self-concept is weak. During the past three decades, researchers have developed multifaceted self-concept instruments that demonstrate clear evidence for the multidimensional nature of self-concept construct.

**Multidimensional models.** Researchers now conceptualise self-concept as a multidimensional construct, and have developed self-concept instruments to measure specific facets of self-concept that are at least loosely based on explicit theoretical models such as that proposed by Shavelson et al. (1976). Exploratory and confirmatory factor analysis has been applied to evaluate the validity of these a priori facets. Reviews of this research (Byrne, 1984, 1996a; Hattie, 1992; Marsh & Craven, 1997; 2006; Marsh & Shavelson, 1985; Wylie, 1989) demonstrate clear support for the multifaceted structure of the self-concept construct. Subsequently, Marsh and Craven (2006) have emphasised that self-concept cannot be understood adequately if its multidimensionality is ignored.

While Shavelson et al. (1976) have proposed that self-concept is multidimensional and hierarchical, subsequent research (e.g., Marsh & Yeung, 1998) on the self-concept has shown that a multidimensional conceptualisation of the
construct yields greater insight into this central psychological construct that is however somewhat esoteric and elusive. It also facilitates greater application for improving human potential, when its structural aspect is delineated. Specifically, self-concept is more clearly elucidated when its multidimensional nature is examined, as opposed to viewing it only as a unidimensional construct. Shavelson et al. (1976) have presented a pictorial representation (see Fig. 3.1) of a multidimensional, hierarchical model of self-concept. In this model, general self-concept at the apex is divided into academic and non-academic components. The academic component is divided into self-concepts specific to various school subjects, while non-academic self-concept is divided into physical, social, and emotional components, which are further divided into more specific components.

![Figure 3.1. Representation of a hierarchical and multidimensional model of self-concept by Shavelson et al. (1976).](image)

Although the structure proposed by Shavelson et al. was heuristic and plausible (Marsh & Hattie, 1996), it was not supported by empirical research using the self-concept instruments available at that time. Hence, the Self Description Questionnaire (SDQ) instruments were constructed, specifically to reflect this
theoretical model (see Marsh & Shavelson, 1985). The psychometric properties of the three SDQ instruments (SDQI for preadolescents, SDQII for adolescents, and SDQIII for late adolescents and young adults) were established on the basis of this research. For example, the internal consistency of the scales from the three SDQ instruments was shown to be very good—typically in the .80s and .90s (Netemeyer, Bearden, & Sharma, 2003)—and the stability of SDQ responses also was shown to be very good, particularly for older children and adolescents. Many factor analyses of diverse samples differing in gender, age, country, and language have consistently identified the factors that each SDQ instrument is designed to measure (Marsh, 1989) and have demonstrated that the domains of self-concept are remarkably distinct.

Byrne (1996) notes that most instruments measuring self-concept that have been developed since 1980 are multidimensionally structured, and that the general self-concept measure is of limited value, while the detection of a multidimensional structure (which has been repeatedly established using sound psychometric methodology in a multitude of contexts) provides valuable insights that are not available when the self-concept is viewed only as a general unitary entity. Specifically, Marsh and Craven (2006) suggest:

We propose that if specific components of self-concept are logically related to the aims of a particular study, then these specific components will typically be more useful—more strongly related to important criteria, more influenced by interventions, and more predictive of future behaviour—than a single, global component of self-concept that is intended to provide an overall index of self-concept (p. 138).

For example, Craven, Marsh, and Burnett (2003) have shown that focusing on a specific domain of self-concept (e.g., science self-concept) for students is most logically related to the goals of the study and is more appropriate than focusing on a general self-concept.

**Implications for the present investigation.** As self-concept has been demonstrated to be a multidimensional construct, and given the importance of employing a construct validity approach, such that the self-concept domains that are logically and closely related to behaviours of interest are examined, the implication for the present research is that the student decision-making process in choosing and
studying science is perhaps best understood when multiple domains of students’ science self-concept are conceptualised and examined. Thus, in this study, students’ science self-concepts were examined for different domains in science: biology, chemistry, earth and environmental science, and physics. Hence, in the present investigation students’ science self-concept is conceptualised as multidimensional in nature, new instruments were developed to measure these theoretical constructs, and psychometric validation of the newly developed instruments was undertaken to test their salience for secondary students.

**The internal/external frame-of-reference (I/E) model.** In a series of CFA analyses, Marsh and Shavelson (1985) tested the first-order and higher-order structure of the SDQI. While the first-order CFA supported the multidimensionality of the self-concept construct, a number of CFA tests of the varying hierarchical models of the SDQI (including the model of Shavelson et al., 1976) did not fit well with the data. The specific problem was due to the low-to-zero correlations between math and verbal self-concepts. This led Marsh and Shavelson to put forward a hierarchical self-concept model with two academic higher-order factors (math/academic and verbal/academic) and a second-order non-academic self-concept.

Even though the reformulation of the hierarchical model of self-concept by Marsh and Shavelson (1985) provided a model that was more strongly supported by the data, the question of low-to-zero correlations between math and verbal self-concept remained. Marsh (1986) attempted to explain why these two academic components of the self were so distinct, which led to formulation of the Internal/External (I/E) frame of reference model. The model developed was drawn from a mixture of social comparison theory and self-referent comparison processes, and ultimately was based on theorising that the lack of relation between math and verbal self-concepts was specifically due to two competing comparison processes stemming from two alternate sources: external and internal frames of reference.

According to this model, students compare their perceptions of their own performance through an external frame of reference, with that of other students, through a variety of separate external sources (e.g., school grades, subject rankings etc.). The suggestion here is that a student’s domain-specific self-concept is influenced by their comparisons with other related external sources, so that if they perceive their performance unfavourably in relation to other external sources, their
self-concept will be lower and vice versa. In addition, via an internal frame of reference, students compare their domain specific performance (e.g., science achievement) with another, separate domain-specific performance. As a result of this, if a student perceives their science abilities as better than their verbal abilities, not only will their science self-concept be enhanced, but their verbal self-concept will be weakened. The most important feature of these two frames of reference is that, depending on the weight placed on each comparison process, the external and internal achievement comparisons inevitably cancel the effects of each other out when cross-relations between science and verbal self-concepts are examined.

Given that science and verbal achievements are highly correlated, the external comparison process should see a positive relation between science and verbal self-concepts. Counter-balancing this though, is the internal comparison process where, in comparing the self-achievement both of science and verbal outcomes, there should be a negative correlation between the two resulting self-concepts, wherein science self-concept should be higher than verbal self-concept if the individual’s science performance is stronger (and vice versa). As a result of these competing comparisons, a near zero-order correlation should exist for both science and verbal self-concepts (Marsh, 1986).

**The reciprocal effects model.** Self-concept researchers (e.g., Byrne, 1996a; Marsh, 1990b, 1993a; Marsh et al., 1999) have attempted to resolve the theoretical ‘‘chicken-egg’’ debate whether academic self-concept ‘‘causes’’ academic achievement or academic achievement ‘‘causes’’ academic self-concept. Marsh and Craven (2006) contrasted self-enhancement and skill-development models of the relation between self-concept and achievement. The self-enhancement model suggests that academic self-concept causes achievement, whereas the skill-development model predicts that achievement causes academic self-concept. Byrne (1984) examined longitudinal studies purporting to test causal ordering between self-concept and academic achievement and defined three criteria that such studies must satisfy: (a) a statistical relation must be established; (b) a clearly established time precedence must be established in longitudinal studies; and (c) a causal model must be tested using appropriate statistical techniques, such as structural equation modelling (SEM). Calsyn and Kenny (1977) and, to a lesser extent, subsequent researchers have attempted to address the chicken-egg debate by evaluating the causal predominance of academic self-concept and performance; that is, they have
compared the sizes of effects leading from prior achievement to subsequent self-concept with the sizes of effects leading from prior self-concept to subsequent achievement. However, rather than this either-or approach, Marsh and Craven (2006) proposed the Reciprocal Effects Model (REM) wherein self-concept and performance share a mutually reinforcing and dynamic reciprocal relation. Thus, prior self-concept affects subsequent performance and prior performance affects subsequent self-concept. Marsh and Craven (2006) have provided an overview of new support for the generality of the REM for young children, cross-cultural research in non-Western countries, health (physical activity), and non-elite (gymnastics) and elite (international swimming championships) sport. They suggest that subsequent reviews elucidating the significant implications of self-concept for theory, policy, and practice need to account for research supporting the REM and a multidimensional perspective of self-concept. The relations of gender and age differences with self-concepts are discussed next.

**Gender and Age Differences in Self-Concept**

Gender studies provide clear support for a multidimensional perspective of self-concept. Though gender differences in self-esteem typically are small (Wylie, 1979), there are small differences favouring boys, which grow larger through high school and then decline in adulthood (Kling, Hyde, Showers, & Buswell, 1999). While these small gender differences in self-esteem mask larger, counterbalancing gender-stereotypic differences in specific components of self-concept (e.g., boys have higher math self-concepts than girls, girls have higher verbal self-concepts than boys), the pattern of these differences is reasonably consistent from early childhood to adulthood (e.g., Crain, 1996; Eccles et al., 1993; Marsh, 1989, 1993a). Marsh (1993b) found support for a gender-invariant model of self-concept in which relations among math, verbal, academic, and general self-concepts do not vary as a function of gender or age. Similarly, Watt (2004) found that gender differences favouring boys for math self-concept and girls for verbal self-concept were stable and did not vary with age.
Limitations of Unidimensional Approaches to the Study of Gender Differences in Self-Concept

In a study based on a sample of German adolescents, Marsh, Trautwein, et al. (2006) demonstrated that although there were stereotypic gender differences in the mean levels of math self-concept, patterns of relations among math self-concept, math interest, math school grades, and math test scores were similar for boys and girls. Hence, the richness of gender differences in self-concept cannot be understood from a unidimensional perspective. The research on gender differences in multiple dimensions of self-concept is also relevant to related research on androgyny (e.g., Marsh & Byrne, 1991; Marsh & Myers, 1986). The evaluative part of the self-concept is often referred to as self-esteem (Stets & Burke, 2005). Self-esteem is also commonly referred to as the general self-concept in the self-concept literature (Marsh & Craven, 2006). This persistent finding, sometimes referred to as the “masculine supremacy effect” has led many researchers to suggest a masculinity model of relations between gender and self-esteem, rather than an androgyny model. Marsh and Byrne (1991) demonstrated that this apparent lack of support for the importance of femininity was due in part to overreliance on a unidimensional perspective of self-concept. When measures of masculinity and femininity were related to multidimensional self-concept measures, the relative contributions of masculinity and femininity varied substantially for different areas of self-concept, and femininity contributed more positively than masculinity to self-concepts that were stereotypically feminine. Marsh and Byrne found that support for this differentiated androgyny model was consistent among both males and females, for both self-responses and responses by significant others, and across five age groups in early to middle adolescence. Marsh and Craven (2006) declared that the relations of self-concept to masculinity and femininity cannot be adequately understood if the multidimensionality of self-concept is ignored.

Students’ Self-Concepts in Science and Its Causal Influences on Achievement-Related Outcomes

Chiu (2008) refers to science self-concept as the confidence that students have in their capacity to learn science. Hence, it is reasonable to consider that across many educational settings a positive self-concept would be valued as a desirable or critical goal (Australian Educational Council, 1989; Brookover & Lezotte, 1979). In support
of deeming self-concept to be an important educational factor, previous research has shown that higher levels of self-concept are linked to various education outcomes, such as: academic effort, coursework selections, educational aspirations, and academic achievement (e.g., Marsh, 1990a; Marsh & Craven, 1997; Marsh & Hau, 2003).

In a study of university students enrolled in first-semester general chemistry classes over the course of an academic year, Lewis, Shaw, Heitz, and Webster (2009) found that the number of students who possessed low self-concept in general chemistry at post-secondary level was significantly high. Given that self-concept has been found to be an important driver of achievement, this is of concern. Yeung et al. (2010) examined whether the cognitive and affective components of self-concept are domain specific. They also examined whether parents’ influence on children’s academic behaviours and choices is also domain specific. The participants in their study were secondary students (seventh grade) from a secondary school in Singapore. A sample of secondary students were asked to respond to survey items about their self-concepts in learning physics and English, and their perceived parent expectations in physics. It was found that parental influences on students’ self-concept in physics tend to be strong. Similarly, Senler and Sunger (2009) have reported that family involvement was directly linked to elementary school students’ self-concept, task value, and achievement in science.

Students’ perceptions of themselves (self-concepts) play an important role in their personal aspirations and in their self-expectations (Lynch, 1991), and also influence their academic achievement (Byrne & Shavelson, 1986; Hansford & Hattie, 1982; Purkey, 1970; Shavelson & Bolus, 1982; Taylor & Michael, 1991). For example, Marsh and Koller (2003, 2004), interpreting the relations among students’ math/science achievements and their math/science learning self-concepts found that math/science achievement had a positive effect on math/science self-concept. Furthermore, Chien, Jen, and Chang (2008) using a motivation-resource competition model by employing structural equation modelling, examined the influences of academic self-concept on academic achievement. They found that a student’s self-concept in one learning subject (math or science) had a positive effect on his/her achievement in the same subject, but a negative effect on achievement in another learning subject (science or math). Chien et al. (2008) also found that students with
higher academic self-concept tended to invest more time engaging in learning activities in the corresponding learning subject.

A longitudinal study by Handley and Morse (1984) examined relations of attitudes and achievement in science with self-concept and gender role perceptions of seventh and eighth grade students over a two-year period. They concluded by saying “that both attitudes and achievement in science were related to the variables of self-concept and gender role perceptions of male and female adolescents” (p. 599). These relations, however, were more evident in association with attitudes than with achievement in science. Furthermore, research has found that boys tend to have better math and science self-concepts than girls (Eccles, 1982; Eccles et al., 1983; Eccles & Jacobs, 1986; Fennema, 1983; Linn, 1989).

Thus, the above research findings suggest that there is a positive relation between students’ science self-concept and achievement in school science. However, given the multidimensional nature of self-concept, a comprehensive study has not been conducted to investigate students’ self concepts in different disciplines of high school science, such as biology, chemistry, earth and environmental science, and physics, across age and gender. Hence, little is known as to the nature and relation of science domain specific self-concepts to achievement in specific science subjects (Chandrasena, Craven, Tracey, & Dillon, 2012). Thus, one of the goals of the present investigation is to investigate and explore the relations of the multi-dimensional facets of secondary students’ science self-concepts with their science aspirations and achievement.

The Significance of Motivation

Motivation has been defined as “the internal state that arouses, directs, and sustains students’ behavior towards achieving certain goals” (Zeyer & Wolf, 2010, p. 2217). According to Senemoğlu (2004), motivation is the repulsive power of an organism towards attaining a certain goal, towards being able to do the necessary actions in particular conditions, giving energy direction to behaviours, causing an effective advance. It is a power that enables achieving a state wherein one is able to reach certain goals. Being in, a motivated state results in an individual’s ability to maintain interest and attention, in their willingness to make an effort over a necessary period of time to achieve certain results, focusing on the object in view, not giving up in difficult circumstances, and generally maintaining resolution. It is considered that
displaying all these characteristics would influence both the academic achievement and the anxiety level of an individual.

Based on research findings in mathematics, Tella (2007) states that highly motivated students perform better academically than low-motivation students. Similarly, Bank and Finlapson (1996) and John (1996) have reported that academic achievement is highly correlated with students’ motivation. Therefore, students’ motivation is believed to have a significant influence on learning outcomes (Martin, 2003; Martin, Marsh, & Debus, 2001, 2003; McInerney, 1995; McInerney, Roche, McInerney, & Marsh, 1997; Pintrich & DeGroot 1990; Schunk 1990; Yeung & McInerney, 2005).

Motivation is generally believed to be crucial for effective learning. Researchers have also found that better motivated students perform better in school grades and other achievement outcomes (e.g., Pintrich, 2003). While traditional models of school motivation distinguished between intrinsic and extrinsic motivation (see Spaulding, 1992), more recent models of school motivation have examined the goal orientations of students. Goal theory focuses on students’ perceived goals and purposes for learning (Seifert, 2004); that is, their reasons for doing a task. Hence, achievement goal orientations are presumed to be linked to achievement processes and outcomes (Pintrich & De Groot, 1990; Pintrich & Schrauben, 1992), and students’ goals provide a framework for interpreting learning situations (Pintrich, Marx, & Boyle, 1993). The theoretical background to the measurement of goal orientation is presented next.

Theories of Motivation

There are a few theories of motivation as and they have been explained briefly next.

Expectancy–Value Theory

The constructs of the expectancy and value theoretical models have a long history in the field of psychology and expelling in the achievement motivation field (Weiner, 1992; Wigfield & Cambria, 2010; Wigfield & Eccles, 1992). Social psychological theories of attitudes, intentions, and their relations to behaviour such as the theory of reasoned action and the theory of planned behaviour are based in part of expectancy and value constructs. Expectancy has been defined as our beliefs about the future and
value has been considered as the psychological experience of being attracted to an object or activity.

**Attribution Theory**

Weiner (1974) found close links between attribution theory and achievement theory. Achievement theory suggests that people seek pride in accomplishment or avoid the shame of failure. Weiner (1980) feels it is not just the success or failure of activities that engender pride or shame but also the explanations the person attributes to the causes of success or failure. Hence, this theory is an explanation of the beliefs people have about why they behave in the way they do.

**Social Cognitive Theory**

Social cognitive theory emphasizes dual control-systems in the self-regulation of motivation, namely a proactive discrepancy production system that work in concert with a reactive discrepancy reduction system (Bandura, 2001). As noted earlier research on social cognitive theory shows empirically that the effect of environmental antecedents and consequences are mediated by cognitive variables. According to this theory people are motivated by the foresight of goals, not just the hind sights of short falls. A specific high goal creates negative performance discrepancies to be mattered. So, people mobilize their effort and resources based on their anticipatory estimates of what is necessary for goal attainment.

**Goals and Goal Orientations**

Though social cognitive theories of motivation generally hypothesize that individual’s thoughts, beliefs, and emotions influence motivation, in recent years these theories have emphasized the importance of goals and goal orientation when explaining students’ patterns of achievement behaviour. Pintrich and Schank (2002) defined goals as “cognitive representation of students’ purposes in achievement situation and are motivating forces that direct management of students’ learning and achievement” (p. 5). According to this theory individuals have goals in their mind, either to reach or avoid even though the goals may not be well formulated and can alter with experience.

*The measurement of goal orientations.* Achievement goal theories have usually focused on two answers to the question of why students engage in a learning
task. Those students who engage in a task with the purpose of improving their level of competency and understanding are said to hold a mastery goal orientation. In contrast, students who engage in a task primarily to show superiority with reference to others are said to hold performance (or ego-related) goals. Hence, performance goals focus on evaluations of relative ability (Ames, 1992), self-worth (Covington, 2004), and on gaining favourable judgements from others, rather than on effort. Performance-oriented individuals can exhibit either approach or avoidance tendencies, depending on their self perceptions of competency (Elliot, 1999).

Research has consistently found that mastery goals are associated with adaptive motivational behaviours, including perseverance with difficult tasks (Nadler, 1998; Ryan & Pintrich, 1998), preference for challenging tasks (Sarrazin, Famose, & Curry, 1995; Seifert, 2004), and maintaining effort, interest, and value in learning (Linnenbrink, 2005; Robins & Pal, 2002). Thus, research on achievement goal theory has constantly indicated that the extent to which students report pursuing mastery goals varies positively with their achievement outcomes. Whereas the salience and positive effect of mastery goals seem relatively universal (McInerney et al., 2003), the research evidence on the relation between performance goals and achievement is not so clear (Covington, 2004).

Performance-approach goals have been linked to mastery-like achievement patterns on some occasions (e.g., Elliot & Church, 1997), but less so on other occasions (e.g., Elliot, McGregor, & Gable, 1999). Though motivational models developed from various theories have led to the creation of different constructs, with a wide variety of names and labels, both traditional and more recent models of school motivation essentially have emphasised a distinction between constructs parallel to the intrinsic-extrinsic dichotomy. While some instruments with different names may measure the same underlying construct, those with the same name may also measure completely different underlying constructs. Thus, Marsh (1994) has warned researchers to beware of jingle-jangle fallacies in motivation research. Marsh, Craven, Hinkley, and Debus (2003) emphasise that researchers should pursue construct validity vigorously to test interpretations of the measures so as to avoid “jingle” (assuming that scales with the same name reflect the same construct) and “jangle” (assuming that scales with different names reflect different constructs) fallacies” (p. 192). Despite a greater emphasis on multiple dimensions in modern motivation models (e.g., McInerney, Marsh, & Yeung, 2003), more recently,
research has demonstrated that the various dimensions can be more or less subsumed under a limited range of constructs.

Marsh, Craven, Hinkley, and Debus (2003) reviewed a wide range of motivation literature relevant to the Big-Two-Factor Theory of motivation orientation. They identified seven major motivation constructs: Mastery, Intrinsic, Cooperation, Individual, Competition, Ego, Approach Success, and Avoid Failure. Marsh et al. (2003) then constructed a new measure, known as the School Motivation Questionnaire (SMQ), for each of these seven scales, with four to six items measuring each scale. In the present study, Mastery, Intrinsic, and Ego Motivation scales were used to investigate high school students’ science motivation in different disciplines such as biology, chemistry, earth and environmental science, and physics. The research background to students’ science motivation is discussed in the next section.

Students’ Motivation in Science

A body of research has also investigated the relations among indicators of motivation, such as academic goals, perceived ability, and outcomes such as persistence and achievement goals. Hidi and Harackiewicz (2000) argue that lack of ability and lack of effort contribute to students’ unsatisfactory performance and motivation. They also argue that an absence of academic motivation and lack of interest is also likely to influence students’ neglect of their study. Studies have also shown that as children get older, their interests and attitudes toward science tend to deteriorate (Eccles & Wigfield, 1992; Eccles, Wigfield, & Schiefele, 1998; Epstein & McPartland, 1976; Haladyna & Thomas, 1979; Hoffmann & Haussler 1998). Surprisingly, some research has also found a negative relation between Intrinsic Motivation and academic achievement. For example, Devetak, Lorber, Jurisevic, & Glazar, (2009) found that students in Year 8 and 9 who exhibited a higher level of Intrinsic Motivation to learn chemistry did not perform better.

Hassan (2008) found that male students had higher scores for motivation for science, self-concept of ability, and enjoyment of science, while female students had higher scores for lack of anxiety than did male students. Hassan concluded that attitudes toward general science among Australian tertiary and secondary school students are significantly different for male and female students. However, given the multidimensional nature of constructs, a comprehensive study of motivation has not
been conducted in different disciplines of high school science, to ascertain whether motivation varies for different areas of science. The present investigation aims to contribute to addressing this gap in the literature by exploring students’ science motivation in different disciplines of science and by investigating its relation to students’ science aspirations and achievement.

The Significance of Aspirations
Aspirations can be simply recognised as strong desires or ambitions for high achievement (Astone & McLanahan, 1991). As an educational outcome, educational aspirations are linked with higher levels of self-concept (Marsh, 1990a; Marsh & Craven, 1997; Marsh & Hau, 2003). Given the finding of a positive relation between self-concept and academic achievement, it could also be argued that there might be a positive relation between educational aspirations and achievement (Fox & Faver, 1981) though there is a dearth of research on this area.

In examining potential change in students’ aspirations through the high school years, Yeung and McInerney (2005) have shown that seventh-graders had significantly higher career aspirations than ninth-graders. Yeung and McInerney also examined the relations between mastery, performance, and extrinsic motivation orientations and aspiration outcomes, and found that all goal orientations were positively associated with both aspiration outcomes: education aspirations, which refer to students’ aspirations to study beyond secondary education, and career aspirations, which refer to students’ aspirations to better careers after their secondary studies. Educational aspirations were also relatively consistent across grades. However, a significant drop in career aspirations was present in Grade 9; this rose again in Grade 11. This result therefore warrants further investigation.

Students’ Aspirations in Science
Successive training experiences are necessary for students to consider a career in science (Berryman, 1983). Hanson (1996) later distinguished four dimensions, or pipelines, along which students experience science: access, activity, achievement, and attitudes. In a recent quantitative study, Gilmartin, Li, and Aschbacher (2006) drew on Hanson’s ideas and operationally defined the science pipeline for that study as including curricular and extracurricular activities, achievement, attitudes, behaviours, and choices that prepare high school students for college and work in the
Asbacher, Li, and Roth (2010) explored these pipeline dimensions not only in the physical sciences and engineering, but also in biological and environmental sciences, medicine, and other science-related careers, such as nursing, lab technician, and science teaching. Workforce concerns exist, not only in regard to who will be the next generation of research scientists but also for those who will have desirable middle-class jobs applying scientific knowledge and practices, in occupations that also suffer shortages and high turnover (Buerhaus, Auerbach, & Staiger, 2007; Ingersoll, 2007). Such jobs may also be more accessible to low income and minority students.

According to Asbacher, Li, and Roth (2010), students expressed positive attitudes toward science and non-science pursuits where they experienced success and received support from important people in their lives. These results underscore the key role of communities in career and identity development, and suggest a need for interventions to help socialisers (e.g., teachers, parents etc.) better understand the value and purpose of science literacy themselves, so as to encourage students to appreciate science, to be aware of possible career options in science, and to enjoy learning and doing science.

Science identity is the sense of who students are, what they believe they are capable of, and what they want to do and become with regard to science (Brickhouse, 2001). Within a situated learning framework (Brickhouse, 2001), science identity is informed by students’ lived experiences and social interactions at home, in school, and in the larger world. It is based on how students view themselves and believe others view them as they participate in scientific endeavours. Students may participate in multiple social communities, where they must negotiate their identities back and forth in terms of the rules and values set up by these communities (Furman & Barton, 2006; Lave & Wenger, 1991). Thus, a student’s science identity is likely to change and evolve over time. Webb, Mary, David, Benbow, and Persson (2002) reported that many individuals who completed nonmath-nonscience degrees ultimately chose math-science occupations (and vice versa).

Given the strong evidence for the multidimensional nature of constructs, it is surprising that a comprehensive study has not been conducted in the past to investigate students’ aspirations in different disciplines of high school science, such as biology, chemistry, earth and environmental science, and physics. Thus, in this investigation education and career aspirations in different domains of science were
investigated through scales adapted from Yeung and McInerney’s (2005) School Motivation and Aspiration Scale.

**Implications for the Present Investigation**

Past research studies have investigated the relations between students’ self-concepts and motivation, and aspirations and achievement in general science. However, due to the multidimensional nature of the psychological variables being examined, it is essential to investigate students’ self-concepts, motivation, and aspirations in different disciplines of science such as biology, chemistry, earth and environmental studies, and physics. This investigation does that by using a survey instrument that was developed for different disciplines of science.

Science is a very broad topic that has distinct, yet related branches or disciplines. Biology is the area of science in which students study living matter such as plants, animals, and their habitats. In Chemistry the emphasis is on chemical elements, compounds, structures (atoms, molecules, ions, lattices etc.), and chemical reactions and uses of matter. Earth & Environmental Science is the study area of science where students study the universe, paying more attention to the earth and its environment. In this area the main emphases are on rocks, on life in earlier times, dynamic earth, space travel, the universe—stars in particular—and the earth’s environment, with special attention being given to issues related to environmental change. Physics is the area of science where studies are conducted on different types of energy (electricity, sound, heat, mechanical, etc.), forces (magnetic, gravitational etc.) and their uses.

Since past research has not investigated the relation of students’ science self-concepts and motivation to their science aspirations and achievement in the different disciplines of science, the purpose of the present study is to contribute to addressing this gap in the literature by: (a) testing the psychometric properties of a suite of new instruments to measure the multidimensional domains of secondary students’ science self-concepts, motivation, aspirations; (b) explicating the relations between students’ multidimensional domains of science self-concepts and motivation and their science aspirations and achievement in high school science, testing the extent to which relations vary across gender and age; and (c) elucidating students’ and teachers’ perceptions of the barriers to participating in science education.
Chapter Summary

Constructs serve to link theory with empirical research, and are the fundamentals of theory (Bergman, 2010). Thus, an understanding of their nature and use is essential in research, especially in the behavioural sciences, where constructs are routinely conceptualised, defined, measured, and analysed as a means of understanding human behaviour better. This chapter has discussed the nature and the use of constructs, both generally and in the context of this present investigation. Moreover, the importance and the use of construct validity have been discussed in this chapter. Self-concept, motivation, and aspirations were identified as important constructs for the present investigation. These constructs provide an ideal context for further explicating the nature of constructs, while establishing the theoretical foundations of the methodology used in this research to address the overarching research aims and questions. The research aims, hypotheses and research questions pursued in the present investigation are discussed in the next chapter.
CHAPTER 4

RESEARCH AIMS, HYPOTHESES, RESEARCH QUESTIONS, AND THEIR RATIONALE

There are no statistical adjustments to correct for having asked the wrong research question (Hetherington, 2000, p. 42).

Introduction

The present investigation has as its central purpose to elucidate the relations between secondary students’ multidimensional science self-concepts, motivation, and aspirations. To address this overarching purpose, three interrelated studies comprise the present investigation. These studies aim to:

1. Develop a psychometrically sound survey instrument that measures secondary students’ science self-concepts, motivation, and aspirations in different domains of science (i.e., biology, chemistry, earth and environmental science, and physics; Study 1);

2. Test and explicate the relations of science multidimensional self-concepts and motivation with aspirations and academic achievement of Australian secondary students across gender and age, in different domains of science (i.e., biology, chemistry, earth and environmental science, and physics; Study 2); and

3. Further elucidate the nature of Australian secondary students’ and teachers’ views, practices, and personal experiences by undertaking qualitative data analysis to enrich and extend the findings from the quantitative component of the investigation (Study 3).

The aim of Study 1 is to investigate the psychometric properties of a newly developed survey instrument—the Science Self-Description Questionnaire (SSDQ)—as a measure of five distinct subscales of science self-concept: general
science, biology, chemistry, earth & environmental science, and physics; the Science Motivation Questionnaire (SMQ) as a measure of five distinct subscales: general science, biology, chemistry, earth & environmental science, and physics; and the Science Aspirations Questionnaire (SAQ) as a measure of five distinct subscales: general science, biology, chemistry, earth and environmental science, and physics for secondary students across gender and age levels. Study 2 continues from Study 1 and investigates the relations of secondary students’ science self-concepts and motivation to science aspirations and achievement in the different disciplines of high school science across gender and age levels.

Study 3 is qualitative in nature and uses interviews and focus groups with selected students and teachers to provide “the opportunity to step into the mind of another person, to see and experience the world as they do themselves” (McCracken, 1998, p. 9). It was intended that interviews would allow for an in-depth examination of the issues raised in the quantitative data, and provide further insights not captured in Study 2.

The purpose of this chapter is to present the overarching aims, hypotheses, and research questions, including their rationale, for each of the three studies that comprise the present investigation. Hypotheses have been formulated where previous theory and research provides adequate research-based evidence to inform predictions. Research questions have been posed where existing theory and research are not sufficient to make predictions. The aims for each of the studies, which form part of the present investigation, precede the hypotheses and research questions relevant to each study. Each hypothesis and research question has been numbered so that the aim it relates to within each study can be clearly identified. Thus, Hypothesis 1.1.1 refers to Study 1, aim 1, Hypothesis 1; Research Question 1.2.1 refers to Study 1, aim 2, Research Question 1, and so on. Similarly, the rationale for each hypothesis is presented with a clear title so that it too may be easily linked to its corresponding aim and hypothesis or research question.

**Study 1: Psychometric Properties of the Instrumentation**

**Introduction**

Testing the psychometric properties of the instrumentation (a within-construct investigation) employed in the present investigation is a fundamental measure enabling confident testing of the relations amongst sets of variables related to
secondary students’ self-concepts, motivation, and aspirations, and their achievement in science (a between-construct investigation).

In this section, firstly, a set of research aims is provided, followed by a set of research hypotheses and questions to address these aims. This section concludes by providing rationales for the research hypotheses and questions posed for Study 1.

The Problem
Are the survey instruments used in the present investigation psychometrically sound for the total sample of secondary students, as well as for the male and female subgroups, and lower, middle, and upper secondary school students? To what extent do the instruments possess acceptable psychometric properties, as demonstrated by: (a) internal consistency of the component scales, (b) a valid factor structure that adequately represents the constructs the instrument is hypothesised to measure, and (c) the invariance of each instrument’s scales across various subgroups (e.g., males/females, secondary stages of schooling: early, middle, upper)?

Measurement Scales and Subscales of the Secondary Science Questionnaire (SSQ)
In the social sciences, measurement scales are used to measure or order entities with respect to quantitative attributes or traits (DeVellis, 2003). For example, a scaling technique might involve estimating individuals’ levels of extraversion, or the perceived quality of products. Certain methods of scaling permit estimation of magnitudes on a continuum, while other methods provide only for relative ordering of the entities. Sub-scales are the sub-divisions of a scale. For example, the science self-concepts scale might have subscales that match the different science disciplines, such as biology, chemistry, physics, and earth and environmental science. Sub-scales include different items related to particular attributes. The individuals’ level of agreement or disagreement on these items is measured using a point scale.

The SSQ comprises the previously mentioned measurement scales: SSDQ, SMQ, and SAQ. Table 4.1 provides a summary of these measurement scales, with sample items for each of the subscales that comprise the measurement scales of the Secondary Science Questionnaire (see Appendix A for full instrument breakdown). Each of the subscales is measured on a six-point Likert scale (1 = strongly agree to 6
= strongly disagree). The terms “construct” and “factor”, are used interchangeably throughout this thesis.

Table 4.1
Summary of the Measurement Scales and Their Respective Subscales

<table>
<thead>
<tr>
<th>Measurement Scale</th>
<th>Sub-scales(^3)</th>
<th>Sample Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Self-Description Questionnaire (SSDQ)</td>
<td>Science Self-Concept (04)</td>
<td>“I am good at SCIENCE”</td>
</tr>
<tr>
<td></td>
<td>Biology Self-Concept (04)</td>
<td>“BIOLOGY is one of my best subject areas”</td>
</tr>
<tr>
<td></td>
<td>Chemistry Self-Concept (04)</td>
<td>“I look forward to CHEMISTRY classes”</td>
</tr>
<tr>
<td></td>
<td>Earth and Environmental Science Self-Concept (04)</td>
<td>“I enjoy studying for EARTH &amp; ENVIRONMENTAL SCIENCE”</td>
</tr>
<tr>
<td></td>
<td>Physics Self-Concept (04)</td>
<td>“I often need help in the subject area PHYSICS”</td>
</tr>
<tr>
<td>Measurement Scale</td>
<td>Sub-scales(^a)</td>
<td>Sample Items</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Science Motivation Questionnaire (SMQ)</td>
<td>Science Motivation (12)</td>
<td>“I feel most successful in SCIENCE when I reach personal goals”</td>
</tr>
<tr>
<td></td>
<td>Biology Motivation (12)</td>
<td>“I do BIOLOGY because I like learning new things”</td>
</tr>
<tr>
<td></td>
<td>Chemistry Motivation (12)</td>
<td>“I do CHEMISTRY because I like to solve hard problems”</td>
</tr>
<tr>
<td></td>
<td>Earth and Environmental Science Motivation (12)</td>
<td>“I feel most successful in EARTH &amp; ENVIRONMENTAL SCIENCE when I am the best”</td>
</tr>
<tr>
<td></td>
<td>Physics Motivation (12)</td>
<td>“I feel most successful in PHYSICS when I do something I could not do before”</td>
</tr>
<tr>
<td>Science Aspirations Questionnaire (SAQ)</td>
<td>Science Aspirations (20)</td>
<td>“I hope I continue my SCIENCE studies”</td>
</tr>
<tr>
<td></td>
<td>Career Aspirations (15)</td>
<td>“I wish to get a good job in SCIENCE”</td>
</tr>
</tbody>
</table>

\(^a\)The number of items for each subscale is given in parentheses after the subscale name.
Aims

Dimensionality, reliability, and validity are important facets of a scale’s psychometric properties and quality (Furr, 2011). Zumbo (2007) states that “without validation, any inferences made from a measure are potentially meaningless, inappropriate, and of limited usefulness” (p. 48). According to Pedhazur and Pedhazur Schmelkin (1991), poor measures cannot be compensated by profound theoretical formulations, sophisticated designs, and elegant analytical techniques. Thus, Study 1 aims to test the psychometric properties of the:

1. SSDQ (see Appendix A for a breakdown of scales and items) as a measure of five distinct subscales of science self-concept: general science (hereafter called “science”), biology, chemistry, earth and environmental science, and physics, for secondary students for the total group, and for the subgroups of males and females, and for lower, middle, and upper secondary students;
2. SMQ (see Appendix C for a breakdown of scales and items) as a measure of mastery, intrinsic, and ego orientations in science, biology, chemistry, earth and environmental science, and physics for secondary students for the total group, for males, females, and for lower, middle, and upper secondary students;
3. SAQ (see Appendix D for a breakdown of scales and items) as a measure of five distinct scales of science and career aspirations: science, biology, chemistry, earth and environmental science, and physics, for secondary students for the total group, males and females, and for lower, middle, and upper secondary students; and
4. Outcome variables and the measurement battery (SSDQ, SMQ, SAQ, and teachers’ and students’ ratings on science achievement) in terms of the factorial integrity of the latent constructs of the separate scales when grouped together in a single battery.
Schematic Representation of Factors (Latent Variables) and Their Indicator Variables

In the discussion that follows, several references to factor structures are given when discussing the research aims and hypotheses. Figure 4.1 shows an example of a pictorial representation of a factor structure, with the factors and their respective items. In each diagram, an ellipse represents the factor or latent variable, while rectangles represent the observed variables (i.e., survey items). An arrow radiating out from the factor towards the item indicates that the response given to the item is caused by the factor. Arrows originating from the right hand side represent error measurements. Errors are also assumed to cause or contribute to the observed item score, and are latent variables because they cannot be directly observed. While errors could be represented by ellipses in structural model diagrams, because they are latent variables, it is customary to represent them only by arrows. Curved arrows between factors represent co-variation between factors.

A desirable attribute of a subscale is that it is a measure of one, and only one factor (see Chapter 5). To achieve this condition, for each factor structure of the SSQ, there should be no correlations between the error terms, and no cross loadings (i.e., no item is permitted to load onto more than one factor).

Figure 4.1. Example of a schematic representation of a factor structure
Statement of Hypotheses and Research Questions

Hypothesis 1.1.1: The Science Self-Description Questionnaire (SSDQ) will yield acceptable reliability estimates for each factor for the total sample, as well as for critical groups. Using Cronbach’s Alpha as the measure of reliability, it is hypothesized that the SSDQ will yield acceptable reliability estimates for each factor for the total sample, as well as for critical groups (males/females, stages of secondary schooling: early, middle, upper).

Hypothesis 1.1.2: The SSDQ will yield acceptable overall model fit in confirmatory factor analysis. Using confirmatory factor analysis as a method of assessing factorial structure it is hypothesized that the a priori factor structure of the SSDQ (see Figure 4.2) will demonstrate acceptable overall model fit, demonstrating the multidimensionality of the science self-concept constructs.

Hypothesis 1.1.3: The SSDQ will demonstrate factorial invariance for Gender. It is hypothesized that the a priori factor structure of the SSDQ will be invariant for males and females.

Hypothesis 1.1.4: The SSDQ will demonstrate factorial invariance for secondary school stage. It is hypothesized that the a priori factor structure of the SSDQ will be invariant for early, middle, and late secondary schooling stages.
Figure 4.2. Factorial structure of SSDQ
Note: Subscales GS = General Science, BG = Biology, CH = Chemistry, EE = Earth & Environmental Science, PH = Physics.
Hypothesis 1.2.1: The Science Motivation Questionnaire (SMQ) will yield acceptable reliability estimates for the total sample, as well as for critical groups. Using Cronbach’s alpha as the measure of reliability, it is hypothesized that the SMQ will yield acceptable reliability estimates for each factor for the total sample, as well as for critical groups (males/females, stages of secondary schooling: early, middle, upper).

Hypothesis 1.2.2: The SMQ will yield acceptable overall model fit in confirmatory factor analysis. Using confirmatory factor analysis as a method of assessing factorial structure, it is hypothesized that the a priori factor structure of the SMQ will demonstrate acceptable overall model fit (Figure 4.3 shows the overall structure of the SMQ and Figure 4.4 shows the structure of each subscale).

Hypothesis 1.2.3: The SMQ will demonstrate factorial invariance for Gender. It is hypothesized that the a priori factor structure of the SMQ will be invariant for males and females.

Hypothesis 1.2.4: The SMQ will demonstrate factorial invariance for secondary school stage. It is hypothesized that the a priori factor structure of the SMQ will be invariant for early, middle, and late secondary schooling stages.
Figure 4.3. Multidimensional structure of the science motivation questionnaire (SMQ) Note: Subscales GS = General Science, BG = Biology, CH = Chemistry, EE = Earth & Environmental Science, PH = Physics.
Figure 4.4. Each subscale structure of the Science Motivation Questionnaire (SMQ)

**Hypothesis 1.3.1:** The Science Aspiration Questionnaire (SAQ) will yield acceptable reliability estimates for the total sample, as well as for critical groups. Using Cronbach’s alpha as the measure of reliability, it is hypothesized that the SAQ will yield acceptable reliability estimates for each factor for the total sample, as well as for critical groups (males/females, stages of secondary schooling: early, middle, upper).

**Hypothesis 1.3.2:** The SAQ will yield acceptable overall model fit in confirmatory factor analysis. Using confirmatory factor analysis as a method of assessing factorial structure, it is hypothesized that the a priori factor structure of the SAQ will demonstrate acceptable overall model fit (Figure 4.5 shows the overall structure of the SAQ and Figure 4.6 shows the structure of each subscale).

**Hypothesis 1.3.3:** The SMQ will demonstrate factorial invariance for Gender. It is hypothesized that the a priori factor structure of the SAQ will be invariant for males and females.
Hypothesis 1.3.4: The SMQ will demonstrate factorial invariance for secondary school stage. It is hypothesized that the a priori factor structure of the SAQ will be invariant for early, middle, and late secondary schooling stages.

*Figure 4.5. Multidimensional structure of the science aspirations questionnaire (SAQ) Note: Subscales GS = General Science, BG = Biology, CH = Chemistry, EE = Earth & Environmental Science, PH = Physics.*
Research Question 1.4.1: Structural integrity of the assessment battery.
When all of the measurement scales are combined into one assessment battery, is the factorial structural integrity of the individual instruments maintained when measured using confirmatory factor analysis?

Rationale for the Hypotheses and Research Questions

Rationale for Hypotheses 1.1.1–1.1.4 (Reliability, factor structure, and invariance testing of the SSDQ). In support of deeming self-concept to be an important educational factor, research has shown that higher levels of self-concept are linked to various education outcomes, such as: academic effort, coursework selections, educational aspirations, and academic achievement (Marsh, 1990a; Marsh & Craven, 1997; 2006; Marsh & Hau, 2003). Early research conceived of self-concept as a unidimensional construct, emphasising a single, global measure of self-concept (Byrne, 1984; Wylie, 1979). The limitations of the unidimensional perspective have been well documented (Marsh & Craven, 2006; Wylie, 1979). Whereas early research studied global self-concept, later studies shifted in focus to the measurement of multiple facets of self-concept.

The items relating to secondary students’ science self-concept have been adapted from the Self Description Questionnaire II (SDQ II), developed by Marsh.
(1990), which has excellent psychometric properties when administered to adolescents. In this research the items administered to the secondary students were modified appropriately for each different discipline of science. It is anticipated that the modified items are likely to display similar psychometric properties to that of the SDQ II. On this basis, it is hypothesised that the SSDQ will possess sound psychometric properties, as determined by an assessment of the reliability measures for each subscale, and of the structural validity and invariance properties when used for the sample in this investigation.

**Rationale for Hypotheses 1.2.1–1.2.4 (Reliability, factor structure, and invariance testing of the SMQ).** Byran, Glynn, and Kittleson (2011) have found that students’ Intrinsic Motivation is related to achievement science. According to Glynn, Taasoogshirazi, and Brickman (2006), students’ motivation has a strong direct influence on science achievement. Given this research background, a questionnaire was developed for the purposes of this investigation, to measure students’ motivation in science.

The items relating to secondary students’ science motivation were adapted from the school science motivation questionnaire developed by Marsh, Craven, Hinkley, and Debus (2003), which has excellent psychometric properties for adolescents. The items administered to the secondary students in this research were modified for the different science disciplines. Each discipline (i.e., each subscale) included three factors: Mastery, Intrinsic, and Ego Motivation (see Figure 4.4). It is anticipated that the modified items are likely to display similar psychometric properties to that of the school science motivation questionnaire. On this basis, it is hypothesised that the SMQ will possess sound psychometric properties, as determined by an assessment of the reliability measures for each subscale and of the structural validity and invariance properties, for the sample in this investigation.

**Rationale for Hypotheses 1.3.1–1.3.4 (Reliability, factor structure, and invariance testing of the SAQ).** Aschbacher, Li, and Roth (2010) suggest the need for students to be aware of career options in science. Hence, a scale related to science aspirations has been included in the SSQ. The items relating to secondary students’ science aspirations have been adapted from the Science Educational Aspirations (SA) and Career Aspirations in Science (CA) scales developed by Yeung and Mcinerney (2005). This scale has excellent psychometric properties with adolescents. The items in this research, administered to the secondary students, were modified for
the different disciplines of science. It is anticipated that the modified items will display similar psychometric properties to those of the further education aspirations and career aspirations questionnaires. On this basis, it is hypothesised that the SAQ will possess sound psychometric properties, as determined by an assessment of the reliability measures for each subscale, and of the structural validity and invariance properties, for the sample in this investigation.

Rationale for Research Question 1.4.1 (Structural integrity of the assessment battery). Though each of the three measurement scales may prove to have sound psychometric properties when administered individually, it is important, and a necessity, to check whether they still demonstrate good psychometric properties when all scales are administered together in one sitting. Survey items that load on to more than one factor, the correlation of error terms, and excessively high correlations between factors are some of the possible threats to the construct validity of measurement scales (Hair et al., 2006). Hence, it is necessary to see how the individual measurement scales and their subscales relate, when combined. In order to answer this, a research question was posed to explore the issue. It is expected that the measurement scales of SSQ will demonstrate the hypothesised factor structure, while individual items will load on the factors that they are intended to measure.

Section Summary
The importance of using a psychometrically sound survey instrument in social research is well recognised. Few researchers would entertain the idea of using survey instruments they did not believe were capable of accurately measuring the variables of interest to a study’s research questions. For this study, research questions and hypotheses were developed to investigate the psychometric properties of the SSQ. The SSQ consists of three measurement scales that together comprise 15 subscales. Each measurement scale was separately assessed for reliability, structural validity, and invariance. In addition, a research question was proposed, to ensure that the psychometric integrity of the three measurement scales is maintained when administered as a single test battery.
Study 2: Explicating the Science Multidimensional Self-Concepts, Motivation, Aspirations, and Academic Achievement of Australian Secondary Students

Introduction
Study 2 seeks to explore the nature of students’ self-concepts, motivation, and aspirations in the different disciplines of science across gender and age level. This study also investigates the relations between a set of predictor variables (students’ self-concepts and motivation) and a set of outcome variables (aspirations and achievement in different disciplines of science) for the total sample, males and females, and for students in different stages of secondary schooling (early, middle and late). A set of research aims is provided, followed by a set of research questions to address these aims. This section finishes with a set of rationales for the research questions.

The Problem
To what extent do Australian secondary students’ multidimensional science self-concepts, motivation, science aspirations, and achievement vary for the total sample and as a function of age and gender?

Aims
The aims for Study 2 are to test:

1. The extent to which multidimensional self-concepts in science vary for the total sample, males and females, and for students in different stages of secondary schooling (early, middle, late);
2. The extent to which science motivation varies for the total sample, males and females, and for students in different stages of secondary schooling (early, middle, late);
3. The extent to which science aspirations vary for the total sample, males and females, and for students in different stages of secondary schooling (early, middle, late);
4. The extent to which science achievement varies for the total sample, males and females, and for students in different stages of secondary schooling (early, middle, late); and
5. The relations between science self-concepts and motivation, aspirations and science achievement.

**Statement of Research Questions**

**Research Question 2.1.1:** Differences on SSDQ facets for the total sample. To what extent will students’ science self-concepts vary among the different science subject areas of science, biology, chemistry, earth and environmental science, physics, and general science self-concept?

**Research Question 2.1.2:** Differences on SSDQ facets for the sample across gender. To what extent will students’ science self-concepts in different science subject areas vary across gender?

**Research Question 2.1.3:** Differences on SSDQ facets for the sample across students in different year levels. To what extent will students’ science self-concepts in different science subject areas vary across students’ different year levels of secondary schooling?

**Research Question 2.2.1:** Differences on SMQ facets for the total sample. To what extent will students’ science motivation vary in science?

**Research Question 2.2.2:** Differences among SMQ facets for the sample across gender. To what extent will science motivation vary across gender?

**Research Question 2.2.3:** Differences among SMQ facets for the sample across students in different year levels. To what extent will science motivation vary across different year levels of secondary schooling?

**Research Question 2.3.1:** Differences in science educational and career aspirations for the total sample. To what extent will students’ aspirations vary in relation to science education and career?

**Research Question 2.3.2:** Differences in science educational and career aspirations across gender. To what extent will science aspirations vary in science across gender?

**Research Question 2.3.3:** Differences in science aspirations for the sample across students’ year levels. To what extent will science aspirations vary across students’ different stages of secondary schooling?

**Research Question 2.4.1:** Differences on science achievement for the total sample. To what extent will science achievement vary in science?
Research Question 2.4.2: Differences on science achievement for the total sample across gender. To what extent will students’ science achievement vary across gender?

Research Question 2.4.3: Differences on science achievement for the total sample across students’ year levels. To what extent will students’ science achievement vary at different stages of secondary schooling?

Research Question 2.5.1: Relations of students’ science self-concepts with science aspirations. What are the relations between science self-concepts and science aspirations?

Research Question 2.5.2: Relations of students’ science self-concepts with science achievement. What are the relations between science self-concepts and science achievement?

Research Question 2.5.3: Relations of students’ science motivation with science aspirations. What are the relations between science motivation and science aspirations?

Research Question 2.5.4: Relations of students’ science motivation with science achievement. What are the relations between science motivation and science achievement?

Rationale for the Research Questions 2.1.1–2.5.1

Yeung et al. (2010) found that parental influences tend to affect students’ self-concepts in physics. Similarly, Senler and Sunger (2009) have reported that family involvement was directly linked to elementary school students’ self-concept, task value, and achievement in science. Handley and Morse (1984) also found that both attitudes and achievement in science were related to the variables of self-concept and gender role perceptions of male and female adolescents.

Oliver and Simpson (1988) have researched the effects of academic self-concept and science motivation on academic achievement, and suggest that motivation predicts academic success. House (1993) has also suggested that motivation has a significant effect on achievement. Previous research has also shown that higher levels of self-concept are linked to various education outcomes, such as academic effort, coursework selections, educational aspirations, and academic achievement (e.g., Marsh, 1990a; Marsh & Craven, 1997; 2006; Marsh & Hau, 2003).
However, no comprehensive study has been conducted to investigate the relations between students’ science self-concepts and motivations and aspirations and achievement in the different disciplines of science, such as biology, chemistry, earth and environmental science, and physics. Thus, a series of research hypotheses and questions pertaining to Study 2 were posed, to explore the relations between the variables under consideration. While correlations between pairs of variables provide useful information, additional valuable information can be gained when sets of variables (i.e., two or more variables) are incorporated in a structural equation model and used to predict the outcome variables. The predictive relations amongst variables of the SSQ have not been explored in previous research. Hence, research questions were posed to explicate this issue in Study 2.

**Study 3: A Qualitative Examination of the Associations between Australian Secondary Students’ Science Self-concepts, Motivation, Aspirations, and Achievement**

**Introduction**
Qualitative research is a tradition in social science that depends on watching people in their own territory and interacting with them in their own language on their own terms (Kirk & Miller, 1986). Qualitative data were gathered in this investigation to help the data triangulation process, so as to enrich the quantitative findings. Thus student focus groups and teacher interviews were conducted, in order to investigate students’ science self-concepts, motivation, aspirations, science achievement, and their relations.

**The Problem**
How do Australian secondary students’ science self-concepts, motivation, and aspirations vary for the different subject areas in science, across gender and different stages of schooling? To what extent do these qualitative findings illuminate and enrich the quantitative findings?
Aims

Study 3 aims to:

1. Explicate secondary students’ decision-making processes in deciding whether or not to pursue science subjects at school and in post-schooling options;
2. Identify students’ science self-concepts, motivation, aspirations, science achievement and their relations in different disciplines of science;
3. Identify additional themes that may not be easily identifiable from the quantitative findings of Study 2, to provide additional and enriched insights into students’ science self-concepts, motivation, aspirations, and achievement; and to;
4. Identify the factors that influence secondary school science education, from teachers’ perspectives.

Statement of Research Questions

Research Question 3.1.1: What influences secondary students’ decisions to undertake science subjects at school?

Research Question 3.1.2: What influences secondary students’ decisions to undertake post-secondary education in science?

Research Question 3.2.1: To what extent do science self-concepts relate to science aspirations?

Research Question 3.2.2: To what extent do science self-concepts relate to science achievement?

Research Question 3.2.3: To what extent does science motivation relate to science aspirations?

Research Question 3.2.4: To what extent does science motivation relate to science achievement?

Research Question 3.3.1: Are there other issues that influence students’ decision making process on whether or not to pursue further science education options?

Research Question 3.4.1: What do teachers believe influences secondary students’ decisions to undertake science subjects at school?

Research Question 3.4.2: What do teachers believe influences secondary students’ decisions to undertake post-secondary education in science?
Research Question 3.4.3: What other issues beyond the immediate school context identified by teachers, influence students’ decision-making process regarding whether or not to pursue further science education?

Rationale for the Research Questions 3.1.1–3.3.1

As discussed in Chapter 2, past research has shown that the decline in science enrolments is related to many interrelated factors, such as students’ academic abilities, teaching methods, the absence of motivation to study science, and a lack of interest in science subjects (Hassan & Treagust, 2003). Dayton (2012) reports that Australia’s Chief Scientist, Professor Chubb claims high school students are disengaged and disinterested, shunning science courses, viewing them as irrelevant. Further, Chubb considers that students think science is boring (Hall, 2012). However, research is yet to elucidate this issue in relation to different disciplines of science.

Thus, a series of research questions pertaining to Study 3 were posed to investigate students’ and teachers’ views pertaining to science education in schools, to provide further insights into the findings from Study 2 and to facilitate the triangulation of data.

Chapter Summary

This chapter has presented statements of the problem, aims, hypotheses, research questions and their rationales, for each of the three studies that comprise the present investigation. Given the diversity of issues in this investigation, as well as the limitations of relying on a single method design (i.e., either a quantitative approach or a qualitative approach), a mixed-methods design was adopted, to address the investigation’s overarching aims. The next chapter presents the methodology employed in each of the three studies comprising the present investigation.
CHAPTER 5

METHODOLOGY

A key feature of mixed methods research is its methodological pluralism or eclecticism, which frequently results in superior research (Johnson & Onwuegbuzie, 2004).

Introduction

This research comprised three related studies addressing the research hypotheses and research questions outlined in Chapter 4. Together they constitute a mixed-methods research design, with the first two studies being quantitative in nature, and the third qualitative. The aims of the three studies have been described in detail in Chapter 4, but are summarised here as follows:

Study 1: The aim of this study is to investigate the psychometric properties of a newly developed survey instrument: the Secondary Science Questionnaire (SSQ) for secondary students.

Study 2: This study follows from Study 1 and uses advanced statistical techniques to address the hypotheses and research questions posed for Study 2. Specifically, the SSQ is used to investigate whether a set of predictor variables (comprising varying psychological constructs of the instrument such as science self-concepts and science motivation) can be used to predict a set of outcome variables (science aspirations and science achievement).

Study 3: For Study 3, structured interviews with relevant stakeholders (students and teachers) were undertaken, to provide rich insights
into the relations between secondary students’ science self-concepts and motivation and their aspirations and science achievement, and to identify additional issues that may not necessarily be identifiable from the quantitative findings of Study 2. Hence, Study 3 was designed to bolster the findings from Study 2 and to expand upon the results.

The purpose of this chapter is to describe the methodology used for each study. Firstly, a rationalisation for the methodological approach taken, the mixed-methods design, is presented. Secondly, the methodological issues common to all three studies are presented. Finally, methodological issues unique to each of the three studies are examined for each study separately.

Mixed-Methods Design

What is a Mixed-Methods Design?
The mixed-methods approach combines quantitative and qualitative research methods into a single design (Tashakkori & Teddlie, 1998). Considering 19 different definitions, Johnson, Onwuegbuzie, and Turner (2007) defined mixed-methods research as a:

Type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration (p. 123).

For topics of a complex nature, a combination of qualitative and quantitative techniques is useful for investigating the beliefs, opinions, and practices of participants. This combination has the potential to offset many of the limitations of each method when used in isolation, as well as consolidating and elucidating additional findings illuminated by either method (Cresswell, Clark, Gutmann, & Hanson, 2003; Tashakkori & Teddlie, 2003, 2009). Given these advantages, it is not surprising that mixed-methods designs are increasingly espoused as important to the
development of sound research findings and to interpretations of component data (Marsh, Martin, et al., 2006).

**Choosing a Mixed-Methods Design**
A mixed-methods design is more than just the arbitrary combining of quantitative and qualitative research techniques; it is a research design with philosophical assumptions (Creswell and Clark, 2006). Based on the type of research being conducted, and its purpose, there are different typologies (i.e., different combinations of techniques) to choose from. The typology used in this research is the sequential explanatory design which, as described by Hanson, Creswell, Clark, Petska, and Creswell (2005), is where quantitative data are collected then analysed, followed by the collection of qualitative data. The collected qualitative data are analysed and usually are used to enrich the quantitative data.

**The Advantages of Combining Quantitative and Qualitative Methods**
Mixed-methods researchers, in bringing together the benefits of both qualitative and quantitative approaches to research, often claim greater validity of results as a reason for their methodological choices (Buber, Gadner, & Richards, 2004). Mixed-methods designs can provide realistic advantages when exploring complex research questions as the qualitative data provide a deep understanding of survey responses, and statistical analysis can provide a detailed assessment of patterns of responses (Driscoll, Yeboah, Salib, & Rupert, 2007).

Mixed methods design emerged in response to the limitations of the sole use of quantitative or qualitative methods, and this approach is now considered by many a legitimate alternative to these two traditions (Doyle, Braddy, & Byrne, 2009). The utilisation of qualitative research methods provides access to the lived reality of individuals, facilitating the exploration of people's internal constructions of their personal worldview (Morgan & Drury, 2003). Further, Sechrest and Sidani (1995) argue that “quantitative observations may be subjected to rational analysis that leads to verification by qualitative observation” (p. 78). Moreover, mixed-methods designs can provide pragmatic advantages when exploring complex research questions.

Conducting research using mixed-methods is also referred to as triangulation by some researchers (e.g., Mathison, 1988; Webb, Campbell, Schwartz, & Sechrest, 1966). In the social sciences, triangulation is often used to indicate that more than
two methods are used in a study, with a view to doubling (or tripling) check results. This is also called "cross examination" (Cheng & Liying, 2005). Triangulation is a powerful technique that facilitates validation of data through cross verification from more than two sources. Altrichter, Feldman, Posch, and Somekh (2008) contend that triangulation "gives a more detailed and balanced picture of the situation." However, using the process of triangulation does not necessarily mean that all findings will agree with one another. On the matter of contradictory findings, Mathison (1988) asserts that the method of triangulation rarely provides a clear path to a singular view, since contrary and contradictory findings are common. She further adds that by expecting that triangulation will result in a singular valid proposition, researchers look for the convergence of evidence and miss the greater value of triangulation (i.e., identifying diverse findings). Torrance (2012) argues that triangulation is an important component of mixed-methods design; it has its origins in attempts to validate research findings by generating and comparing different sorts of data and different respondents’ perspectives on the topic under investigation. The appropriate use of qualitative techniques for this research is discussed later in this chapter, in relation to Study 3.

In this research, statistical analyses of survey responses were conducted in conjunction with an analysis of qualitative data derived from interviews with students and teachers, to gain a richer and pluralistic insight into students’ and teachers’ perceptions about the secondary students’ science self-concepts, motivation, aspirations, and science achievement.

Johnson and Onwuegbuzie (2004) state that the goal of mixed-methods research is not to replace either quantitative or qualitative approaches but rather to draw from the strengths and minimise the weaknesses of both, in single research studies and across studies. Thus, it is apparent that each methodological approach has its own strengths and weaknesses. The purpose of this discussion is not to elevate one research method above the other, but to demonstrate the advantages of a mixed-methods approach in addressing a set of research questions. It is expected that findings from all three studies will complement each other, even perhaps providing findings that are mutually exclusive or apparently contradictory.

In sum, the use of multiple methods in research can contribute to methodological rigour (Patton, 2002), by creating synergistic research where one method (i.e., quantitative or qualitative) enables the other to be more effective
(Hesse-Biber & Leavy, 2011). Johnson, Onwuegbuzie, and Turner (2007) argue that ‘‘Mixed methods research . . . is becoming increasingly . . . recognised as the third major research approach or research paradigm . . . We currently are in a three . . . research paradigm world, with quantitative, qualitative and mixed methods research all thriving and co-existing’’ (p. 117). More specifically, while this researchcapitalises on state-of-the-art statistical techniques, it also recognises that interviewing a sample of students and teachers will provide rich insights into the experiences of students that are not easily captured using quantitative methods.

**Research Participants and Recruiting Procedures**

**Ethical Considerations**

Before approaching potential participants for this research, ethics approval was required from the University of Western Sydney (UWS) Human Research Ethics Committee. Approval was obtained by completing a National Ethics Application Form and submitting it to the committee. Once ethics approval was obtained from UWS, the New South Wales Department of Education and Communities (DEC) was also approached, to submit the necessary documents for the State Education Research Approval Process (SERAP), to obtain permission to conduct the research in high schools. In this process the principal investigator and the other four supporting staff members working on this survey undertook a criminal record check before working in schools and were made aware of NSW Child Protection Act and the requirements of treatment of children in schools.

**Participants**

A focus of this research is examining the relations between secondary students’ science self-concepts, motivation, aspirations, and achievement in science across gender and age levels. To fulfil this goal, four high schools in New South Wales were invited to participate in this research, with three schools agreeing to participate. Once schools agreed to participate, students from all three schools and science teachers from two of the participating schools were invited to participate. Consent forms were distributed to parents/guardians via the schools, to obtain permission to allow their children to participate in the survey. Teacher consent forms were also distributed through schools to obtain teachers’ consent to participate in interviews.
This procedure resulted in 395 students from three secondary schools and 11 teachers from two participating schools participating in the research.

**Recruiting Procedures for Schools and Teachers**

Once DEC ethics approval was received, public schools (secondary) were selected on the basis of geographic location (attempts were made to draw a representative sample of three schools within NSW) and student population of the school. DEC assisted in selecting schools for this survey. Four school principals were asked if they wanted their school to participate in the research study. Letters explaining the project and issues regarding privacy were sent to the schools. Once schools agreed to participate, science teachers from two schools were invited either for face-to-face interviews at the school premises or for phone interviews. The information letters and consent forms including information on the project and confidentiality were sent to schools to be distributed to schoolteachers. Science teachers from two schools were invited either for face to face interviews at the school premises or for over the phone interviews. With the teacher consents, one science teacher from each year level from Year 7 to Year 12 from each of the two schools participating in interviews participated in an interview. All teacher interviews were held on school premises.

**Recruiting Procedures for School Students**

The information letters and consent forms were sent to schools for distribution to the parents/guardians of students in Years 7–12 for their signatures to consent for their children to participate. Students that returned their parental consent forms were invited to participate in a 30–40 minute survey. Participation was on a voluntary basis. All participants were provided with an information letter that outlined all details of the study. All participants were required to sign a consent form indicating that they had read and understood the information letter, before commencing to participate.

Based on students’ responses to the student questionnaire, a small number of students (i.e., 20% of the total sample of 395 students) were invited to participate in a 30-minute semi-structured focus group discussion, with 5–6 students per focus group. Before students could participate, parental/guardian consent and signatures were obtained, followed by student consent. Science teachers from two schools were invited to participate either in face to face interviews at the school premises, or over
the phone interviews. One science teacher from each year level, from Year 7 to Year 12, participated in interviews. All teacher interviews were held on school premises.

**Distributing letters to students of DEC schools to take home.** To monitor participation, principals were contacted, to answer any questions they may have and to ascertain whether or not their school was agreeable to participating by distributing letters to schoolteachers and parents. Of the four school principals approached with a letter of invitation (see Appendix B), three agreed to participate. Principals distributed an invitation to participate in the study, based on informed consent, to schoolteachers (see Appendix C), who distributed parental permission letters to students (see Appendix D).

A total of 2,000 letters to parents were sent out, to three NSW public high schools. The parent consent form return rate was approximately 20%. The actual number of students participating in the survey was 395.

**Study 1: Psychometric Properties of the Instrumentation**

**Overview**
This section commences with a discussion of the design and development of the SSQ, followed by a description of the essential first stage of data analyses (i.e., data screening, tests for reliability and unidimensionality). These techniques were utilised to conduct the preliminary data analyses deemed necessary for assessing the psychometric properties of the SSQ. The advanced statistical technique of confirmatory factor analysis (CFA) is introduced next, to describe the specific analytical methods used to assess the psychometric properties of the SSQ. Three important applications of CFA for this research were validation of the measurement scales, identification of group differences (e.g., Do the students in Years 7 and 8 possess more positive science self-concepts than the students in years 9 and 10?), and the identification of relations among latent variables (e.g., is level of students’ achievement positively correlated with their self-concept?). Both these applications are described in the final part of this section.

**Initial Considerations**
The survey instrument was designed to collect data that could be analysed using advanced statistical procedures, to address the overarching research aims and
questions of this thesis. As analyses should be dictated “first and foremost by a strong theoretical base” (Hair et al., 2006, p. 714), survey items were developed on the basis of relevant theory and research. Consistently with the overarching aim of this research, survey items were carefully chosen that addressed domains of students’ self-concept, motivation, and aspirations in different domains in science (biology, chemistry, earth and environmental science, and physics).

Components of the SSQ
The SSQ comprises the following measurement scales: the Science Self-Description Questionnaire (SSDQ), the Science Motivation Questionnaire (SMQ), and the Science Aspirations Questionnaire (SAQ). Table 4.1 provides a summary of these measurement scales, with sample items for each of the subscales that comprise the Secondary Science Questionnaire. Each of the subscales is measured on a six-point Likert scale (1 = strongly agree to 6 = strongly disagree).

The SSQ survey instrument (see Appendix A, also see Table 4.1 for a list of scales and sample items) is divided into four sections: demographics, the science self-description questionnaire scale (SSDQ), the science motivation questionnaire scale (SMQ), and the science aspirations questionnaire scale (SAQ).

Demographics. This section (see Appendix A) was very brief, and was aimed to collect demographic information (e.g., age, gender, languages spoken, resources available) about the student completing the survey. In addition, some basic information regarding the students’ science achievement was collected in general science and in the different disciplines of science, using a 1-5 Likert Scale.

Science self-description questionnaire scale (SSDQ). This scale comprises survey items related to students’ science self-concepts. The self-concept is a psychological construct of a complex nature (see Chapter 3). To address this complexity, advice based on the findings of Marsh and Craven (2006), was adopted. Due to the multidimensional nature of students’ science self-concepts, this scale includes the following six subscales: biology, chemistry, earth and environmental science, physics, science (in general), and general school. Students’ self-concepts were measured by a researcher-devised multidimensional measure, the science self-concept description questionnaire (SSDQ) developed from Marsh’s (1990) self description questionnaire II. (see Appendix A).
The science motivation questionnaire scale (SMQ). The SMQ was adapted from a motivation scale developed by Marsh, Craven, Hinkley, and Debus (2003) to measure science motivation. Among the different types of orientation in motivation, some researchers have found that ego (Jessie, Philip, Moore, & Lourdusamy, 2003), mastery (Tanaka & Yamauchi, 2000) and intrinsic (Adelman, 1978; Adelman & Taylor, 1983) orientations are significantly correlated with academic achievement. Thus, the SMQ comprises three different motivational orientations: mastery, intrinsic, and ego, in different science domains (see Appendix A).

Science aspirations questionnaire scale (SAQ). Higher achievers in science are more likely to have clear post-secondary plans and to plan academic science-related pathways, than lower achievers (Adamuti-Trache & Sweet, 2009). Aschbacher, Li, and Roth (2010) underscore the key role that communities have to play in career and identity development and suggest a need for interventions to help significant others (e.g., teachers, parents) better understand the value and purpose of science literacy themselves, so as to encourage students to appreciate science, to be aware of possible career options in science, and to enjoy learning and doing science. Educational aspirations and career aspirations were measured by a scale adapted from Yeung and McInerney’s (2005) school motivation and aspirations scale.

Administration of the Survey
A paper version of the survey was developed, along with a consent form attached to the front of the survey (see Appendix A). Suitable dates and the times for the administration of the survey were negotiated with school principals, counselors, and the respective teachers. Surveys were administered in pre-booked school halls and classrooms, with minimal disturbance to normal school work and procedures. Before the surveys were administered, the necessary instructions and other information were explained to the students. At the beginning of the survey it was announced to the students that the data collected would be used by the researcher only for research purposes. It was also announced that no individuals would be identified during any phase of the research.

Data Analysis
Overview. Data screening and general analyses (descriptive statistics, reliabilities, frequencies, etc.) were undertaken using SPSS 20.0. Advanced statistical
analyses were performed using Mplus 6.12. Information collected from participants in the survey section (quantitative study) was subjected to descriptive statistical analyses through SPSS. Students’ science achievements were measured by Teacher and Student Ratings. The relations of student science self-concepts and motivation to aspirations and science achievement were investigated through structural equation modelling (SEM). The data collected through the student focus groups and teacher interviews were subjected to thematic and content analyses.

**Treatment of missing data.** Data were screened for missing values to determine if such values were missing at random or missing systematically. Cases that displayed evidence of systematically missing data, or misleading response biases (e.g., blatantly patterned responses not reflective of attempts to understand the questions) were deleted from the analysis (i.e., listwise deletion). This process resulted in a total of 5 participant responses being deleted from the data (0.25% of the sample), leaving a total of 390 participants. Clearly there are disadvantages to this approach, as it can result in a large number of cases being deleted. However, the deletion of only 5 cases from the dataset was unlikely to impact on subsequent analyses. Dealing with data that is randomly missing requires a different approach. A multiple imputation framework was used to treat missing values of the data set. Substitution for a data point is known as "unit imputation". With multiple imputations, each missing value is replaced with a set of plausible values that represent uncertainty about the right value to impute, instead of filling in a single value for each missing value (Rubin, 1987). This missing value treatment resulted in five imputed data sets. These data sets were then analysed using standard procedures for complete data. The mean values were computed for the results obtained from the five data sets in finalising the magnitude of the respective variable.

**Data cleaning.** The data cleaning process ensures that a verification procedure is followed, that checks for the appropriateness of numerical codes for the values of each variable under study. This process is referred to as code and value cleaning, and is one of the first steps in this analysis stage.

Data screening analysis included checking for the assumptions of normality (Hills, 2008; Tabachnick & Fidell, 2007). After the data cleaning and screening processes, the final data set comprised 387 cases.

**Tests of reliability.** Cronbach’s alpha (sometimes referred to as alpha coefficients) is the most frequently used measure of reliability (Byrne, 2006;
Streiner, 2003). However, the use of alpha coefficients for measuring reliability is problematic (see Sijtsma, 2009 for a comprehensive discussion on the problems with Cronbach’s alpha) as it is inflated by scale length, so scales with 10 or more items can give an exaggerated alpha value. Further, Cronbach’s alpha is based on a restrictive one-factor model (Bentler, 2005), where factor variances and error variances are assumed to be equal. However, despite these limitations, it is customary to report alpha values, and so they are reported in this research. Alpha coefficients were obtained for the total sample, as well as for the individual subgroups of interest (i.e., student gender and age groups). There is no universally agreed minimum threshold for a reliability coefficient (Kline, 2009; Urbina, 2004). However, values of .7 or greater are preferred (Netemeyer et al., 2003), and values of at least .6 are considered acceptable (Aron & Aron, 2003).

Unidimensionality. In scale development, it is unidimensionality that is of primary importance (Clark & Watson, 1995). Hair, Black, Babin, and Anderson (2010) explain unidimensional measures as a set of measured variables (indicators) whose variance can be explained by only underlying construct or factor. The item-total correlation and inter-item correlation methods are often used in the scale development process as a means of determining unidimensionality. While these methods have their appeal, in that they are easy to perform, they are not refined enough to identify unidimensionality. Identifying unidimensionality requires the use of more advanced statistical procedures, such as Confirmatory Factor Analysis (CFA).
Establishing the Psychometric Properties of the Survey Instrument

**Confirmatory factor analysis (CFA).** CFA was chosen rather than Exploratory Factor Analysis (EFA) as it is applicable to scales that are theory based and it allows for hypothesis testing. Thus, CFAs were conducted to validate factor structure for each scale in the instrument. In brief, CFA assumes that variation among observed scores for a set of survey items is due to the influence of a hypothesised underlying construct, plus unique measurement error. Use of a CFA requires the researcher to postulate an a priori model structure that depicts a set of relations between a set of observed indicator variables (such as survey item responses) and an underlying construct (Brown, 2006), where the underlying construct is assumed to cause the responses given by participants to the survey items. The hypothesised factor structures used in this research have been discussed in Chapter 4. To assess the structural validity of the six measurement scales (i.e., SSDQ, SMQ, and SAQ) and their 12 associated measurement sub-scales, the following criteria are hypothesised: (a) each measured (or indicator) variable would have a non-zero loading on the factor it was assumed to measure, with zero loadings on all other factors; (b) for each subscale, the factors comprising it would be correlated; and (c) the error terms (also referred to as uniquenesses) for each measured variable would be uncorrelated. The structural validity is assessed using goodness-of-fit statistics generated by Mplus.

For ease of interpretation, CFA models are often represented pictorially; Figure 5.1 provides such an example.
Figure 5.1 depicts the structure of a CFA model with first-order latent factors, as well as two higher-order latent factors. Within this model, a total of 40 indicator items (rectangular boxes) can be observed; these represent individual questions placed within the questionnaire. The effect of the measurement error (uniqueness) on each indicator item is represented by small circles with an arrow pointing towards the indicator item. The latent factors (also known as unobserved variables) are represented by the oval shapes, and a total of six latent factors can be observed within Figure 5.1, four of which are first-order latent factors (latent factors 1–4) and two of which are higher-order factors (higher order 1 and 2). The effect of each latent variable on its indicator (or in the case of the higher-order variables, the effect on the
first-order factor) is indicated by a straight line, with a single arrowhead pointing away from the latent variable. The co-variances among the latent higher-order factors are represented by curved lines with double-headed arrows. In the higher-order model depicted there are three factor co-variances to be estimated. As a condition set within all CFA analyses in this investigation, each indicator item is set only to load upon its designated latent factor, and no correlations of uniqueness are allowed. Each indicator item is hypothesised to load only on its respective factor, and no correlations between the error terms are hypothesised.

With the overall structure of a CFA now available, the next step is to determine how closely the actual data represents the theoretical a priori model. This process is often called model fitting. Ultimately, it sees the production of a number of ‘goodness-of-fit criteria’ that aid in the interpretation of the model fit. However, at this point it is important to realise that establishing construct validity is an ongoing process and is never accomplished in a single testing or by using a single technique. Therefore, establishing the structural validity of the subscales of the survey instrument alone (by confirming the hypothesised a priori factor structure and establishing unidimensionality) does not establish construct validity (Clark & Watson, 1995) but rather, provides support for construct validity.

**Assessing CFA analyses.** Goodness-of-fit indices obtained for any one CFA model assess either the discrepancy between a model’s implied variance-covariance matrix and a sample variance-covariance matrix. The null hypothesis in CFA is that the sample and estimated covariance matrices are equal. The magnitude of the $\chi^2$ increases with increase of the discrepancy between the two matrices. The probability value ($p$-value) represents the probability of obtaining a $\chi^2$ that exceeds the $\chi^2$ value under the null hypothesis. Hence, a high $p$-value (e.g., $> .05$) is indicative of a good fit between the estimated and sample covariance matrices. However, one of the drawbacks is that the $\chi^2$ statistic is directly proportional to the sample size. Thus, large $\chi^2$ statistics are often generated for large samples, which may suggest (sometimes erroneously) that the covariance matrices are not equal (Byrne, 2006). A vast number of goodness-fit-criteria are available, to use in overcoming this problem. In the present research the recommendations of several researchers were used (e.g., Holmes-Smith, 2008; Hu, Bentler, & Kano, 1992) for evaluating the models in this regard.
Against the vast number of goodness-of-fit criteria available, based on the advice of Coote (2004) and Marsh, Balla, and Hau (1996), the following goodness-of-fit indices were emphasised in the current study: the Root Mean-Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI), and the Tucker-Lewis Index (TLI; also known as the Non-Normed Fit Index [NNFI]). Generally speaking, RMSEA values less than .08 and .05 are deemed to reflect a reasonable fit and a close fit, respectively. In both CFI and TLI, values greater than .90 and .95 reflect reasonable and excellent fits to the data respectively (Browne & Cudeck, 1993; Marsh et al., 1996).

**Practical considerations.** If confirmation is not achieved, based on the specified goodness-of-fit statistics, then the proposed model is rejected, or at least said not to be supported. However, Byrne (2006) states that, considering the costs associated with the collection and analysis of data, it is impractical to terminate research based on a rejected hypothesised model. Hence, a *model-generating* approach is commonly adopted once an initial model is rejected on the basis of a poor fit with the sample data. In this approach, the researcher proceeds to identify the source of misfit and determines a model that better fits the sample data. However, any modifications to the model should not be undertaken solely to obtain a better fit, unless significant justification can be given on theoretical grounds (Hair et al., 2006).

**Invariance testing.** Once each instrument was deemed to be psychometrically sound for the total sample, factorial invariance tests were conducted on each scale of the instrument across the different groups relevant to the present investigation. In investigating the relations between latent factors and their respective indicator variables for a set of data, it is important to determine to what degree the relations hold (or are equivalent) across different groups of interest within a sample (e.g., different age groups, males, and females). Hence, the survey items should measure the same construct comparably across different subgroups of the sample (Brown, 2006). Such recognised equivalence, referred to as *invariance* (Byrne, 2006), is a necessary prerequisite for establishing the validity of the survey scales as well as their generalisability. For this research, two different groupings were of interest: (a) age of the child (i.e., Years 7 & 8, Years 9 & 10, and Years 11 & 12), and (b) gender of the child.

Invariance testing was conducted in a sequential manner, to test the equivalence of model parameters (e.g., factor loadings and factor covariances)
logically and in an increasingly restrictive manner, by constraining the model parameters to be equal (invariant) across designated group levels (Byrne, 2006). Byrne (2012), and Bodkin-Andrews, Ha, Craven, and Yeung, (2010) argue that invariance assumptions involving the error/residual estimated are deemed too restrictive; thus, the emphasis here is solely on the minimal requirements of invariance. The first model is the least restrictive model (completely free), with no between-group invariance constraints placed on the estimated parameters. In the second model, the factor loadings were held invariant across the specified groups. Typically, this is considered the minimum condition of factorial invariance (Byrne, 1998; Cheung & Rensvold, 2002). The first model (M1) is the least restrictive model (completely free), with no between-group invariance constraints being placed on the estimated parameters, and serves as a baseline model (sometimes referred to as “configural invariance”). In the second model (M2), the factor loadings were held invariant across the specified groups, which are typically considered the minimum condition of factorial invariance (Byrne, 1998; Cheung & Rensvold, 2002).

A third invariance model referred to as scalar invariance is sometimes used. However, if the models under investigation are covariance based models, then latent means and item intercepts do not impact on parameter estimates. Therefore metric invariance (M2) is sufficient and is considered the base level of invariance for this investigation (Marsh, Tracey, & Craven, 2006).

Although chi-square difference testing traditionally has been used to estimate invariance, Cheung and Rensvold (2002) find that it is too sensitive for determining overall model fits, especially with larger sample sizes. As a substitute, they recommend that attention be paid to the CFI fit index. Accordingly, there must not be a change of more than .01 in the CFI fit index between M1 and successive models. In addition, overlap in the 90% confidence interval of the RMSEA between M1 and subsequent model M2 is supportive of further invariance (Bodkin-Andrews, Denson, & Craven, 2010).

**Investigating Relations Between Constructs**

Once structural validity is established for the three measurement scales of the SSQ, it is necessary to check that the structural validity of the instrument as a whole is maintained when all subscales are combined. The reason for this is that it is feasible that a subscale from one measure could correlate closely with a subscale from
another measure, to such a degree that the high correlation indicates redundancy of one subscale. Significantly, a high correlation is suggestive that both scales are measuring the same construct. Moreover, it is possible to correlate one or more items from one subscale highly with an item from another subscale. Such cross-correlations compromise the structural validity of the instrument. Simultaneous assessment of the structural integrity of the instrument by administering all the scales together is known as a mass CFA. The mass CFA further facilitates detection of meaningful relations between subscales. Hence, Study 1 postulates a research question to explore the covariance between different subscales of the SSQ (see Chapter 4).

It is of interest to investigate potential group differences for different factors after establishing invariance for the groups (see Chapter 4). For example, do boys’ science self-concepts differ from the science self-concepts of girls? Establishing the invariance of selected characteristics across different group levels (i.e., child gender, child age) allows such questions to be investigated. Based on the principle of Multiple-Indicator-Multiple-Indicator-Cause (MIMIC), the mass CFA was also used to investigate group differences for latent constructs of the SSQ.

MIMIC is considered a stronger statistical technique than traditional multivariate analysis of variance (MANOVA) and multiple regression techniques as it enables a researcher to determine precisely which of the latent variables are predicted by distinct observed variables (Coote, 2004; Kline, 2005; Marsh, Ellis, et al., 2005; Marsh, Tracey, & Craven, 2006). It incorporates both discrete and continuous variables, where the grouping variables are allowed to covary with latent factors. For this research, the previously discussed grouping variables are the discrete variables and the latent SSQ factors are the continuous variables. According to Bodkin-Andrews, O'Rourke, and Craven (2010), paths (i.e., correlations) leading from group variables to latent factors can be interpreted as the potential influence of the grouping variable on the latent variable. In this investigation, MIMIC models were conducted for each of the models examined with CFA and invariance testing. The MIMIC model was assessed by the same goodness-of-fit criteria used for CFA analyses. The correlations and covariances between the latent factors and grouping variables were examined for statistical significance and effect size ($r^2$). The ability to deal with smaller sample sizes is an additional advantage of the MIMIC model.
technique over those required for typical invariance testing and for even more traditional MANOVA techniques (Bodkin-Andrews, O'Rourke, et al., 2010).

Section Summary
This section has described the components of the SSQ and the statistical procedures necessary to achieve the aims of Study 1: namely, evaluation of the psychometric properties of the SSQ and assessing group differences across the scales of the SSQ. An important advanced statistical technique, CFA, was introduced. In the next section the methodology pertaining to Study 2 of the present investigation is described.

Study 2: Explicating the Science Multidimensional Science Self-Concepts, Motivation, Aspirations, and Academic Achievement of Australian Secondary Students

Introduction
Study 1 used CFA to evaluate the psychometric properties of the SSQ and conduct analyses that examine the correlation between variables, where either or both variables may be latent variables or single-item variables. Study 2 examines the relations between variables, where two or more variables can be used to predict a desired outcome (e.g., relation between students’ science self-concept and science achievement). In order to achieve this, Study 2 used an advanced statistical operation known as structural equation modelling (SEM).

Structural Equation Modelling
As SEM is a vast statistical technique, it is impractical to provide a comprehensive description of it in this chapter. A brief introduction is provided in order to facilitate understanding of the statistical methods used in this research. Structural equation modelling (SEM) is a statistical technique for testing and estimating causal relations, using a combination of statistical data and qualitative causal assumptions. This definition of SEM was articulated by the geneticist Sewall Wright (1921), the economist Trygve Haavelmo (1943) and the cognitive scientist Herbert Simon.
(1953), and formally defined by Judea Pearl (2000) using a calculus of counterfactuals.

Structural Equation Models (SEM) allow both confirmatory and exploratory modelling, meaning that they are suited both to theory testing and theory development. Confirmatory modelling usually starts out with a hypothesis that gets represented in a causal model. The concepts used in the model must then be operationalised, to allow testing of the relations between the concepts in the model. The model is tested against the obtained measurement data to determine how well the model fits the data. The causal assumptions embedded in the model often have falsifiable implications which can be tested against the data.

**The structural model.** SEM is employed to examine the relations between predictor variables and outcome variables. The outcome variables could be either latent variables or categorical variables. The *measurement model* describes the relation between a set of indicator variables and their associated respective latent variables, while the structural model shows the relations between latent variables (Byrne, 2006). The measurement model is what is tested when doing a CFA, and the structural model describes relations through structural equations. Diagram 5.2 indicates a schematic representation of a simple structural equation model (also referred to as a path analysis). The structural equations in this investigation are applied to test the hypotheses and research questions for Study 2, as described in Chapter 4.

![Diagram 5.2](image)

*Figure 5.2. Schematic representation of a structural equation model*
An SEM package such as Mplus (Byrne, 2012) can be easily used to develop and test both the measurement and the structural models.

**Advantages of SEM.** According to DeShon (1998), SEM is one of the most popular and powerful statistical techniques in the social sciences. It holds several advantages over standard statistical procedures (Byrne, 1998) and has been derived from the statistical techniques of factor analysis, regression structure, and path analysis. Byrne states that SEM lends itself well to the analysis of data for inferential purposes through patterns of inter-variable relations. In SEM, measurement errors are taken into account, unlike other traditional data analysis techniques, where errors are not considered (DeShon, 1998). Some other advantages of SEM are the feasibility of simultaneous examination of multiple relations between variables and of thorough investigation of hypothetical constructs.

**Evaluating models.** In SEM, a theoretical model is said to fit the observed data to the extent that the model-implied covariance matrix is equivalent to the empirical covariance matrix (Schermelleh-Engell, Moosbrugger, & Müller, 2003). Marsh (1994) recommends a three-step general approach to determine whether the proposed theoretical model is an appropriate fit with the observed data. In the first step, it is necessary to determine that the iterative procedures used in the SEM algorithm converge and that all parameter estimates are mathematically sensible (e.g., no negative variances, no correlations greater than 1). Next, the researcher establishes whether the parameter estimates (e.g., correlations) are reasonable in relation to the a priori model. In the third and last step, the chi-square test statistic and other selected fit indices are evaluated.

**SEM Path Analyses for Study 2**

Figure 5.2 represents a simple structural equation model in which it is indicated that one latent variable is predicting another single latent variable. As with linear regression and path models, several latent and categorical variables can be used, to predict either a single latent or categorical variable. The hypotheses and research questions for Study 2 (see Chapter 4) were answered by testing a set of structural equations. Similarly to linear regression and path models, the analytical process results in beta coefficients and interpretations are drawn for each set of coefficients.
In this investigation, students’ Gender, Year, General Science Self Concepts, Biology Self-Concepts, Chemistry Self-Concepts, Earth and Environmental Science Self-Concepts, and Physics Self-Concepts were treated as the predictor variables. The students’ Science Educational Aspirations, Science Career Aspirations, Teacher Ratings, and Student Ratings were taken as outcome variables. Sometimes, the variance explained by those predictor variables that have individual significant predictive paths does not total the variance explained by the whole SEM model. Likely, this is because the non-significant paths also carry some weight within the whole SEM variance explained estimate.

**Important Considerations of SEM**

Despite the numerous advantages of SEM, Tomarken and Waller (2005) suggest “it is important for clinical scientists to have a balanced perception of its strengths and limitations” (p. 31). One of the limitations is that analyses with latent variables can still be badly affected by the same types of problem that affect multivariate analyses involving single-item indicators (e.g., multiple regression). In the next sections, the following three issues are discussed: multicollinearity, suppression, and the confirmatory nature of SEM, as failure to consider these issues could result in compromised conclusions.

**Multicollinearity.** Marsh, Dowson, Pietsch, and Walker, (2004) suggest that multicollinearity is a “ubiquitous problem that can produce strange, misleading, or uninterpretable results when a set of highly related independent variables is used to predict a dependent variable” (p. 518). Grewal, Cote, and Baumgartner (2004) suggest that researchers sometimes readily neglect multicollinearity, in supposing that the SEM procedures are robust.

The effects due to multicollinearity are not negligible, and should always be considered in any research using multivariate data analysis. Marsh et al. (2004) have provided an example of where failure to consider the effects of multicollinearity resulted in incorrect findings. Examining the work of Pietsch, Walker, and Chapman (2003), Marsh et al. found that the authors concluded that their measure of self-efficacy significantly predicted achievement ($\beta = .55$) while their measure of self-concept ($\beta = -.05$) had failed to do so, despite the two predictor variables being highly correlated ($r = .93$). Given such a high correlation between the two measures (thereby indicating that they are measuring the same variable), one would expect
similar correlations with achievement for both. In reanalyzing the data, Marsh et al.
constrained both paths to be equal and found that the predictive power of both self-concept and self-efficacy were at a realistic level ($\beta = 0.25$). Thus, it was suggested that the inclusion of two highly correlated constructs had produced invalid results due to the effects of multicollinearity.

Grewal et al. (2004) argue that once multicollinearity has arisen, it is exceptionally difficult to alleviate. Hence, they suggest, the best strategy is to avoid it in the first place. Potential solutions for avoiding multicollinearity, suggested by Billings and Wroten (1978) are: increasing sample size, replicating with a different sample, combining the highly correlated predictors into one variable or merging them into a higher-order factor, splitting the analysis into separate blocks, whereby the highly correlated predictors are assessed separately as to their predictive/causal power, and deleting the predictor of least interest. For the present investigation, in instances where multicollinearity might exist, a higher-order factor model is proposed and tested. Such models are common in SEM and CFA, and are easily dealt with using an appropriate SEM application.

**Suppressor variables.** A suppression effect, on the surface, is similar to multicollinearity, with the exception that such effects usually cannot be foreseen, mostly due to lower correlations between the predictor variables (Maassen & Bakker, 2001). A suppression effect can be identified through path analysis when there is a single path from a predictive variable. If a predictor variable that is expected to be correlated positively with an outcome variable is significantly negatively correlated with the inclusion of a second predictive variable that is moderately correlated with the original predictor variable, then it is said that there is a suppression effect.

Darlington (1990) illustrates how the effect of suppression takes place. Suppose a science exam is given in which students only have a short time to complete it (i.e., a speeded exam). The exam scores should match with the measure of students’ knowledge of science, and are very likely to correlate positively with speeded exam scores. Although, the reading speed scores will not necessarily be correlated greatly with knowledge of science, they are useful for predicting a student’s true knowledge of science. This is because variance in students’ speeded exam scores is influenced both by their knowledge of science and by their reading speed. Thus, in this example the students’ reading speed test score is the suppressor variable, as it suppresses unwanted variance in the speed exam scores. This type of
suppression, in which the suppressor variable correlates poorly with the criterion variable but correlates well with other predictor variables, is called classical suppression (Tabachnick & Fidell, 2007).

The unavailability of a statistical test to determine suppression effects is a severe problem with suppressor variables (Smith, Ager, & Williams, 1992). Thus, detection of a suppression effect is a matter of judgement. Further, once detected, the interpretation of a suppression effect is also a matter of judgement. Thus, any interpretation of a suppression effect must be done tentatively, as it is difficult to find out whether a given interpretation is correct or not.

The confirmatory nature of SEM. With SEM it is impossible to confirm that a proposed model is correct (McCoach, Black, & O’Connell, 2007). Thus, the SEM procedure is used to illustrate how well the model fits the available data. However, it may also be possible that other models fit the data (Tomarken & Waller, 2005). Accordingly, Tomarken and Waller (2003) add that there is no statistical test or fit index that can prove that a model is correct—rather, one can only conclude that a well-fitting model is one plausible solution. Thus, adherence to theoretical considerations is very important in order to find a well fitting and meaningful model that makes theoretical sense.

Section Summary
Study 2 utilised an advanced statistical technique (SEM) to explore relations amongst three or more variables (one dependent variable, and two or more independent variables), where the variables may be either single-item variables or latent variables, or both. This study is central to this thesis, as it seeks to investigate the nature of the relations between students’ science self concepts, motivation, aspirations, and achievement of different disciplines in high school science. The SEM procedure has been discussed in detail, with attention being given to the strengths and limitations of SEM procedures.
Study 3: A Qualitative Examination of the Associations between Australian Secondary Students’ Science Self-concepts, Motivation, Aspirations, and Achievement

Introduction

According to Strauss and Corbin (1998), in any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification, the bulk of the analysis is interpretive. Denzin and Lincoln (1994) define qualitative research as multi-method in focus, involving an interpretive, naturalistic approach to its subject matter. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them. Qualitative research involves the studied use and collection of a variety of empirical materials—case study, personal experience, introspection, life story, interview, observational, historical, interactional, and visual texts—that describe routine and problematic moments and meanings in individuals’ lives (p. 2).

Qualitative methodology is not so well regarded in the social sciences as is quantitative methodology (Eby, Hurst, & Butts, 2009). For example, “Qualitative researchers are called journalists, or soft scientists” and “their work is termed unscientific, or only exploratory, or subjective” (Denzin & Lincoln, 2003, p. 12). However, qualitative methodology is increasingly becoming common and popular as a suitable method for research in the field of social sciences, as its strengths are realised and as the limitations of quantitative methodology also are realised. With regard to the value of the first two quantitative studies in the present investigation, it is now recognised that “qualitative data are useful when one needs to supplement, validate, explain, illuminate, or reinterpret quantitative data gathered from the same setting” (Miles & Huberman, 1994, p. 10). This section discusses important features of qualitative methodology in establishing its aptness for use in this investigation. First, a brief discussion of the philosophical foundations of both qualitative and quantitative methods is provided, followed by a discussion of the concepts of validity and reliability. Finally, the specific qualitative techniques and procedures used in this investigation are presented.
A Place for Qualitative Research

**Qualitative versus quantitative methods.** The word “qualitative” implies an emphasis on the qualities of entities and processes and meanings that are not experimentally examined or measured (if measured at all) in terms of quantity, amount, intensity, or frequency. Qualitative researchers stress the socially constructed nature of reality, the intimate relation between the researcher and what is studied, and the situational constraints that shape inquiry. They seek answers to questions that stress how social experience is created and given meaning. In contrast, quantitative studies emphasise the measurement and analysis of causal relations between variables, not processes (Denzin & Lincoln, 2003), whereas quantitative methodology emphasises objectivity, precision, generalisability, and reproducibility. Despite these differences and commonalities, both methodologies can be used together, to attain a common research goal. Thus, it is not desirable to label them as incompatible or antagonistic methodologies.

**Validity and reliability.** The concepts of validity and reliability are very important considerations in any type of research. One of the most frequently raised issues about qualitative research concerns validity. Wolcott (1995) expresses the question at the heart of researchers concerns about validity:

> How do we communicate to our audiences—especially to the more sceptical ones—that what we have reported is what we have seen and understood, and that we recognise, as must they, that it is partial knowledge at best. And how do we reassure ourselves, that what we have seen and understood is what warrants reporting, or that we have gotten it right? (p. 127).

Kvale (1996) states:

> Validity is ascertained by examining the source of invalidity. The stronger the falsification attempts a proposition has survived, the more valid, the more trustworthy the knowledge. Validity comes to depend on the quality of craftsmanship during investigation, continually checking, questioning, and theoretically interpreting findings (p. 241).
In general, both quantitative and qualitative researchers consider validity to be related to the credibility or accuracy of the data they collect, and to the generalisability of the findings. Reliability is perceived to be the reproducibility of findings. However, each group has a different conceptualisation of validity (Ebby, Hurst, & Butts, 2009). Moreover, validity relates to the trustworthiness of findings, while reliability relates to the dependability of the data (Guba & Lincoln, 1989).

Establishing validity and reliability in quantitative studies is based on establishing the use of psychometrically sound survey instruments. However, in a qualitative approach, the researcher is the instrument (Mertens, 2005), and the “credibility of the qualitative methods, therefore, hinges . . . on the skill, competence, and rigour of the person doing the fieldwork” (Patton, 2002, p. 14). The significance of the researcher’s role, in relation to the concept of validity, has been described by Banister, Burman, Parker, Taylor and Tindall (1994):

If we fail to be critically aware and to know ourselves then we are in danger of undermining the validity of our work. Our findings, rather than being firmly grounded in people’s accounts, may merely be a reflection of our own unconscious biases, stirred by the research (p. 150).

Thus, validity and reliability can be maximised when the qualitative researcher has good intentions and clear research aims, and acknowledges his or her potential for bias. In the context of comprehending the concept of validity in qualitative research, Lewis and Richie (2003) suggest that validity relates to the question of “Are we accurately reflecting the phenomena under study as perceived by the study population?” (p. 274). Study 3 was designed to capture the perceptions of teachers and students in relation to their views of school science education, and especially to identify the barriers to undertaking science for secondary students.

The triangulation approach (Greene, 2007; Willig, 2008) was adopted in this research, to maximise validity and reliability. Triangulation is a word often associated with physical measurements in surveying and navigation, where a number of location markers are used to pinpoint a particular spot. In social research and evaluation, the term relates to strategies to overcome the potential bias that can arise from the use of a single method, single data source, single observer, and/or single theoretical base. The concept of triangulation helps to gain a more accurate insight
into a situation through the use of different methods or techniques within a particular methodology (Patton, 2002; Silverman & Marvasti, 2008). In relation to this investigation, triangulation assumes that the use of different sources for collecting data will assist in improving the clarity of research findings (Lewis & Richie, 2003). So for example, with the interview technique, different groups of stakeholders can be used to gain a more representative or reasonable view of the phenomenon of interest.

The qualitative methods used for data collection in the present research were interviews and focus groups. Oakley (1981) states that “Interviewing is rather like a marriage; everybody knows what it is, an awful lot of people do it, and yet behind closed doors there is a world of secrets” (p. 41). Hence, for Study 3, the use of two different interviewee groups (students, teachers) is an example of triangulation.

**Participants**

Based on students’ responses to the student questionnaire, a composite total science attitude score comprising the average of total self-concept, motivation, and aspiration scores was calculated. Students scoring in the top or bottom 10% on this composite score participated in a 30-minute focus group discussion. Separate focus groups were conducted for the top 10% and bottom 10% groups on the science attitude score; 5–6 students were accommodated in each group. Focus groups were conducted for three stage levels (as specified by the New South Wales Department of Education and Communities) by accommodating students separately from Years 7 and 8 (Stage 4), Years 9 and 10 (Stage 5), and Years 11 and 12 (Stage 6). A total of 17 focus groups were conducted, in which 67 students participated. Before students participated, parental/guardian consent and signatures were obtained, followed by student consent. A total of 11 teachers from both schools were interviewed separately.

**Instrumentation**

Semi-structured interview schedules (see Appendix E) were used for teacher interviews and student focus groups. Student interview questions were based on their experience in studying science as a subject and the various disciplines of science, their performance in science, their academic and career aspirations, and their perception of science compared to the other subjects. They were also asked to compare their science subjects with other subjects in relation to level of difficulty, enjoyableness, and their achievement.
Teacher interview questions were based on teaching experience as a science teacher and teachers’ perceptions about science, students’ interests in different disciplines of science, students’ decision-making process regarding continuance of their science studies, and the barriers to undertaking science at school and at post-secondary school levels.

**Procedures**

Both the interviews and focus groups were conducted by experienced researchers. At each school interviews were conducted concurrently, thus reducing opportunity for participants to speak with each other and influence the responses of other participants. Teacher interviews were conducted with individual teachers at the school premises at a time convenient for the teachers. Issues of anonymity and confidentiality were also discussed with participants. Student focus groups were conducted in the allocated rooms at the school premises with selected students from three age stages: Years 7 and 8, Years 9 and 10, and Years 11 and 12.

Before beginning the focus groups the interview questions were read over by the interviewer once for the students, in order to facilitate the discussion. Two printed interview question sheets were also provided to the students for their reference. It was also emphasised with students that their responses were confidential and interviewers were after their honest answers. A brief explanation was also given to students as to why we are doing this research. The following convention was used for the focus groups.

1. Lay the ground rules (which were described next).
2. Before discussions begin, each student should announce his/her name in a clear voice.
3. Before a student talks he/she must raise their hand, and a pencil case (or some other object) is given to them.
4. Only then can he/she talk, and others are to remain silent.
5. Before talking, the student with the pencil case is to announce his or her name before proceeding.
6. Announcing of names is to happen each time a student talks.

The above procedure was adapted to make it easier for the transcribers.
Both the teacher interviews and the student focus groups were recorded using voice recorders. At least two voice recorders were used in each case, as a backup. The researcher also maintained a digital reflexive journal throughout the qualitative study, spending time before and after each day of interviewing, reflecting on perceptions of involvement, any concerns about the data collected, and processes. The reflexive journal is a tool used by many qualitative researchers, to recognise their own role in the process of collecting and analysing data and to give credence to the nuances gleaned from observing the natural surroundings and the behaviours of interview contributors (Lincoln & Guba, 1985; Patton, 2002).

Teacher interviews and student focus groups were copied into computers as audio media (mp3) files and named in such a way as to reflect the day, time, and school where the interviews took place. The data in these mp3 files were transcribed by the researcher, each interview and focus group recording being played over several times. They were later transcribed to a Microsoft Word document.

**Interview and Focus Group Data Analysis**

Interviews and focus groups, predominantly those in the semi-structured format, are the most popular methods of qualitative data collection in psychology (Madill & Gough, 2008). For this research, the interview technique was chosen, since interviews allow us to ascertain things about people that we cannot directly observe (Patton, 2002). Further, Kvale (1996) suggests “If you want to understand how people understand their world and their life, why not talk with them?” (p. 1).

Interviews and focus groups therefore, are an ideal way to gain additional insights into students’ and teachers’ perceptions about science education. Interview data assist in articulating the richness of the data and encapsulating its complexity, allowing the story to be told from an holistic point of view. They facilitate the examination of participants’ perceptions on an historical and event-driven basis.

As mentioned in Chapter 4, sets of research questions in the interview schedules were developed for Study 3, to gain a richer insight into students’ and teachers’ perceptions and personal experiences relating to secondary students’ science self-concepts, motivation, aspirations, and science achievement. All teacher interviews and student focus groups were recorded with the permission of the participants.
The data analysis was carried out through content and thematic analytic approaches. The researcher began with a process of data reduction, followed by analysis, and finally by validation. The researcher employed a range of qualitative analysis tools to deconstruct the interviews, to understand the perspectives of participants, and to identify common and recurring themes. These data analysis tools were both deductive and inductive, from the beginning of the first interview throughout the remainder of the investigation. During this analysis, the researcher listened to each recording over again and made comments along the margin of the transcripts, regarding additional notes on matters such as the tone of the speakers, pauses, interactions amongst participants during the interviews. At this stage of analysis the researcher also reviewed the digital reflexive journal prepared on the day of each interview, to add additional comments to the transcripts, about body language and any other observations from the day. Transcripts from all interviews were treated in this manner, prior to content and thematic analysis.

**Content analysis.** Coding was carried out through selective reduction. The students’ and teachers’ perceptions of the interview questions were assessed through thematic content analysis. The process known as thematic analysis (Patton, 2002, Teddlie & Tashakkorie, 2009), entailing the identifying of critical words, phrases and ideas, allocating codes for the data and thereby establishing a range of themes, too place throughout the analysis phase. For each research question, contrasting views, and where appropriate, consistent patterns and emerging themes were identified by two coders carefully reading through each transcript and coding responses for each theme identified for each research question, and for each case.

The data coding was performed manually by the two coders, using content categories developed utilising an emic approach (i.e., a contextualised approach to reveal the theories and perspectives of the participants) and the key dimensions identified in this component of the study’s conceptual framework. The preliminary analysis formed the basis for collaborative discussion and refinement of the initial coding categories. The analysed transcripts were coded once more, using the themes identified in collaboration with the second coder. Frequency counts were conducted for some of the themes, to maintain a record of the magnitude of issues identified by the contributors (Miles & Huberman, 1994; Patton, 2002). This data display provided a visual and numerical representation of the data and assisted in collapsing themes. The researcher continued to revisit the digital reflexive journal, whole transcripts,
and digital recordings on a regular basis throughout the data analysis process, to ensure that the voices of the participants were being accurately reported. Thus, the interview data was interrogated to discover ideas and patterns and to verify these with other interviews, with the quantitative findings, the reflexive journal, and the research literature. This process of moving between induction and deduction, known as the constant comparative method (Glaser & Straus, 1967; Lincoln & Guba, 1985; Patton, 2002) is an essential aspect of all research. This further scrutinisation helped to identify rich narratives that strengthened the findings of the qualitative component, in relation to the issues of concern in this component of the study.

**Section Summary**

This section has outlined the qualitative methodology technique (interviews and focus groups) used in this research. Before describing the procedures for this component of the present investigation, a justification for the appropriateness of qualitative methodology was furnished. In particular, the topics of validity and reliability were addressed. For this research, interviewing a range of stakeholders (students and teachers) is deemed an ideal approach with which to supplement the findings of the results from the quantitative studies.

**Chapter Summary**

This investigation incorporates three interrelated studies in a mixed-methods research design. A brief, though comprehensive account of the broad methodology utilised has been provided, along with a justification for why such an approach was chosen. It has been suggested that a mixed-methods design helps capitalise on the strengths of both the quantitative and qualitative approaches, while serving to minimise the limitations that occur when only one approach is adopted. The results for each study are presented in turn in the following three chapters.
CHAPTER 6

RESULTS STUDY 1: THE PSYCHOMETRIC PROPERTIES OF THE INSTRUMENTATION

Effective scale construction and adequate quality have important implications for the proper interpretation of psychological research and its psychological meaning (Furr, 2011, p. 2).

Introduction
The psychometric properties of the SSQ are investigated in Study 1. Thus, this chapter presents the results and findings of Study 1 for each of the hypotheses and research questions corresponding to its aims (see Chapter 4). The data are presented in a series of tables, which furnish the basic descriptive statistics (i.e., means, standard deviations, reliabilities), model fit information, factor loadings, and correlations. Conclusions are drawn based on the observed data and results, for each hypothesis and research question.

Overview of the Analyses
Study 1 used advanced statistical methodologies to evaluate a set of hypotheses and research questions. Firstly, the statistical results obtained from SPSS, such as means, standard deviations, and reliabilities for each scale of the instrument were examined. Secondly, the factor structures of each sub-scale and each scale were tested. Thirdly, invariance across gender and year/education stage groups for each scale was checked. Based on the results obtained unlike science self-concepts, students’ science motivation and science aspirations further investigated only in general science as they were not domain specific. Finally, the psychometric properties of all scales when combined together as an instrument battery were examined.
**Inspection of the Descriptive Statistics**

Basic descriptive statistics, such as means, standard deviation, skewness, and kurtosis for the SSDQ are presented in Table 6.1. Since the majority of values for the skewness and kurtosis are close to zero, there are minimal violations in multivariate normality; these are therefore unlikely to impact on the conduct of the CFA.

Inspection of the descriptive statistics in Table 6.1 shows that students’ mean self-concepts in science (general science), biology, and earth and environmental science were higher than those in chemistry and physics for the total sample. Males had higher mean self-concept scores for all the disciplines compared to those for females, except for Biology Self-Concepts. The Biology Self-Concept means for females were higher than those of males, although it remains to be determined whether these differences were statistically significant.

Science and Biology Self-Concept means across the stages, from stages 4 to stage 6 increased, while Chemistry, Earth & Environmental Science, and Physics Self-Concepts increased from stage 4 to 5 and decreased again from stage 5 to 6. Though these are patterns of interest, it needs to be determined whether they are statistically significant. Trends among the various grouping variables are examined for significance when discussing later Research Questions.
Table 6.1

Descriptive Statistics for the Science Self-Description Questionnaire (SSDQ)

<table>
<thead>
<tr>
<th>Grouping Variable</th>
<th>Science</th>
<th>Biology</th>
<th>Chemistry</th>
<th>Earth</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Total</td>
<td>4.46</td>
<td>4.06</td>
<td>3.96</td>
<td>4.00</td>
<td>3.84</td>
</tr>
<tr>
<td>Male</td>
<td>4.59</td>
<td>4.03</td>
<td>4.11</td>
<td>4.01</td>
<td>4.06</td>
</tr>
<tr>
<td>Female</td>
<td>4.37</td>
<td>4.09</td>
<td>3.83</td>
<td>3.99</td>
<td>3.66</td>
</tr>
<tr>
<td>Stage 4</td>
<td>4.41</td>
<td>3.89</td>
<td>3.93</td>
<td>4.00</td>
<td>3.86</td>
</tr>
<tr>
<td>Stage 5</td>
<td>4.47</td>
<td>4.17</td>
<td>4.01</td>
<td>4.05</td>
<td>3.92</td>
</tr>
<tr>
<td>Stage 6</td>
<td>4.90</td>
<td>4.83</td>
<td>3.88</td>
<td>3.79</td>
<td>3.45</td>
</tr>
</tbody>
</table>

| SD Total          | 0.98    | 1.00    | 1.00      | 0.97  | 1.03    |
| Male              | 0.86    | 0.93    | 0.95      | 0.95  | 1.01    |
| Female            | 1.04    | 1.06    | 1.04      | 0.99  | 1.00    |
| Stage 4           | 0.96    | 0.96    | 1.02      | 1.00  | 1.02    |
| Stage 5           | 1.00    | 0.99    | 0.99      | 0.92  | 1.04    |
| Stage 6           | 0.79    | 1.03    | 1.13      | 0.96  | 1.00    |

| Skewness Total    | -0.67   | -0.35   | -0.28     | -0.20 | -0.18   |
| Male              | -0.49   | -0.18   | -0.13     | -0.16 | -0.18   |
| Female            | -0.67   | -0.46   | -0.36     | -0.27 | -0.25   |
| Stage 4           | -0.60   | -0.18   | -0.28     | -0.18 | -0.18   |
| Stage 5           | -0.64   | -0.44   | -0.08     | -0.04 | -0.18   |
| Stage 6           | -0.82   | -0.96   | -0.88     | 0.08  | -0.41   |

| Kurtosis Total    | 0.09    | -0.01   | -0.07     | 0.01  | -0.14   |
| Male              | -0.03   | 0.30    | -0.17     | 0.41  | 0.00    |
| Female            | -0.09   | -0.11   | -0.14     | -0.14 | -0.25   |
| Stage 4           | 0.36    | -0.15   | 0.14      | -0.03 | 0.11    |
| Stage 5           | -0.09   | -0.05   | -0.54     | -0.23 | -0.33   |
| Stage 6           | -0.33   | 0.58    | 0.00      | -0.82 | -0.58   |

*Note. Stage 4 = Early Stage (Years 7 & 8), Stage 5 = Middle (Years 9 & 10), Stage 6 = Late Stage (Years 10 & 11).*
Results Hypothesis 1.1.1: The Science Self-Description Questionnaire (SSDQ) will yield acceptable reliability estimates for each factor for the total sample, as well as for critical groups.

Overview. Hypothesis 1.1.1 proposed that the five factor model of the SSDQ would be a reliable measurement scale for the total sample, as well as for the specific subgroups (stage, gender) such as males and females, and stage 4, stage 5, and stage 6 students of the total sample.

Results. Table 6.2 shows reliability estimates for the SSDQ factors. The results of the reliability estimates for five subscales of the SSDQ for the total sample show acceptable measures, with alpha coefficients ranging between .89 and .90. Acceptable measures of reliability were also obtained across the different subgroups (stage, gender) such as males and females, and stage 4, stage 5, and stage 6 students for the SSDQ (Aron & Aron, 2003), with alpha coefficients ranging from .68 to .91.

Conclusion. Hypothesis 1.1.1 is accepted, as the subscales of the SSDQ demonstrate reliable measures for the total sample, as well as for the specific subgroups of interest (i.e., Stage, Gender).

Table 6.2
Reliability Estimates (Cronbach’s Alpha) for the Total Sample and Subgroups for the Science Self-Description Questionnaire (SSDQ)

<table>
<thead>
<tr>
<th>Grouping categories</th>
<th>Science</th>
<th>Biology</th>
<th>Chemistry</th>
<th>Earth &amp; Environmental Science</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>.90</td>
<td>.90</td>
<td>.89</td>
<td>.90</td>
<td>.90</td>
</tr>
<tr>
<td>Male/Female</td>
<td>.81/.90</td>
<td>.87/.91</td>
<td>.88/.90</td>
<td>.78/.87</td>
<td>.88/.85</td>
</tr>
<tr>
<td>Stage 4/5/6</td>
<td>.89/.86/.82</td>
<td>.89/.87/.90</td>
<td>.90/.89/.88</td>
<td>.90/.89/.68</td>
<td>.91/.91/.77</td>
</tr>
</tbody>
</table>

Results Hypothesis 1.1.2: The SSDQ will yield acceptable overall model fit in confirmatory factor analysis.

Overview. Hypothesis 1.1.2 proposes that the SSDQ would be adequately represented by the five a priori factor structure (see Figure 4.2).

Results. As described in Chapter 5, the statistics used to evaluate the model fit include chi square statistics such as value of chi square ($\chi^2$), degree of freedom
(df), and value of probability (p). In addition, overall fit indices such as root mean square error of approximation (RMSEA), comparative fit index (CFI), and Tucker-Lewis index (TLI) were used to evaluate the model fit. The chi square results for the SSDQ were \( \chi^2 = 433.52, \text{df} = 160, p < .001 \). As the p value is very low (less than .05) the results suggest a poor or unsatisfactory fit (see Chapter 5). However, since the chi square is overly sensitive to sample size, there is a need for consideration of other more stable model fit indices (Byrne, 2006). Thus, the overall model fit indices are acceptable according to the criteria suggested by Marsh, Balla, and Hau (1996), where a CFI and TLI greater than .9 and an RMSEA less than .08 are considered acceptable. Results for the SSDQ were: CFI = .918, TLI = .903, and RMSEA = .066 with a 90% confidence interval of 0.059–0.074.

It is also worthwhile and important to examine the factor loadings of the respective items and the factor correlations for a complete assessment of the factor structure, to ensure items adequately represent the factor structure. Tables 6.3 and 6.4 indicate the factor loadings and factor correlations respectively. Table 6.3 illustrates that every item loading bar one is statistically significant and substantial in size (ranging from .46 to .86). One factor loading was below the base level of acceptability of .5 suggested by Hair et al. (2006), but Hills (2008) emphasises that a factor loading as low as .3 may be acceptable, so this item was retained.

Table 6.3  
Standardised Factor Loadings for the Science Self-Description Questionnaire

<table>
<thead>
<tr>
<th>Items</th>
<th>GS</th>
<th>BG</th>
<th>CH</th>
<th>EE</th>
<th>PH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.82</td>
<td>.79</td>
<td>.76</td>
<td>.77</td>
<td>.71</td>
</tr>
<tr>
<td>2</td>
<td>.65</td>
<td>.46</td>
<td>.60</td>
<td>.50</td>
<td>.66</td>
</tr>
<tr>
<td>3</td>
<td>.75</td>
<td>.85</td>
<td>.80</td>
<td>.86</td>
<td>.86</td>
</tr>
<tr>
<td>4</td>
<td>.73</td>
<td>.84</td>
<td>.86</td>
<td>.85</td>
<td>.86</td>
</tr>
</tbody>
</table>

* All factor loadings are significant at \( p < .05 \)

Note. All parameter estimates are presented in completely standardized format. Of the SSDQ self-concept factors, GS = General Science, BG = Biology, CH = Chemistry, EE = Earth & Environmental Science, PH = Physics.

Table 6.4 shows that factor correlations between general science and the four disciplines of science range from 0.48 to 0.76 and therefore are distinguishable.
Table 6.4

*Factor Correlations of the Science Self-Description Questionnaire*

<table>
<thead>
<tr>
<th></th>
<th>GS</th>
<th>BG</th>
<th>CH</th>
<th>EE</th>
<th>PH</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BG</td>
<td>.72</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH</td>
<td>.76</td>
<td>.68</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE</td>
<td>.62</td>
<td>.59</td>
<td>.59</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>PH</td>
<td>.53</td>
<td>.48</td>
<td>.60</td>
<td>.53</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*All correlations are significant at $p < .05$*

Note. All parameter estimates are presented in completely standardized format. Of the SSDQ self-concept factors, GS = General Science, BG = Biology, CH = Chemistry, EE = Earth & Environmental Science, PH = Physics.

**Conclusion.** A substantial degree of variance in the items is accounted for by their respective factors. The model fit statistics also show a good fit. Thus, Hypothesis 1.1.2 is supported and the five factor model of SSDQ (Figure 6.1) is accepted. These findings provide strong support for the structural validity of the SSDQ.
Results Hypothesis 1.1.3: The SSDQ will demonstrate factorial invariance for Gender.

Overview. Hypothesis 1.1.3 proposed that the a priori five factor structure of the SSDQ would be invariant across gender.

Results. Results for invariance of gender are presented in Table 6.5. As described in Chapter 5, the invariance is evaluated by the application of two multi-group CFA models (M1 and M2). The goodness of fit indices of both of the models
were acceptable for a good fit. The change in CFI values of the two models was used to evaluate the invariance. A change in CFI of less than +/- .01 is supportive of invariance (Cheung & Rensvold, 2002).

The change in CFI between M1 and M2 is less than .01 (i.e., 0.002). Hence, the minimal level of invariance is achieved (Cheung & Rensvold, 2002).

Table 6.5

Summary of Goodness of Fit Statistics for Invariance Testing for the Science Self-Description Questionnaire (SSDQ) Across Gender

<table>
<thead>
<tr>
<th>Model</th>
<th>Model Description</th>
<th>χ²</th>
<th>df</th>
<th>CFI</th>
<th>TLI</th>
<th>RMSEA</th>
<th>90% CI for RMSEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 1</td>
<td>Completely free</td>
<td>599.93</td>
<td>320</td>
<td>.912</td>
<td>.895</td>
<td>.068</td>
<td>.059,—.076</td>
</tr>
<tr>
<td>M 2</td>
<td>FL, IT = Invariant</td>
<td>623.80</td>
<td>340</td>
<td>.910</td>
<td>.900</td>
<td>.070</td>
<td>.058,—.074</td>
</tr>
</tbody>
</table>

Note. χ² = Chi Square, df = degrees of freedom, CFI = Comparative Fit Index, TLI = Tucker-Lewis Fit Index, RMSEA = Root Mean Square Error of Approximation, FL = Factor Loadings, IT = Intercepts.

Conclusion. The goodness of fit indices of the two proposed models demonstrate an acceptable fit. The minimal level of invariance was evident for gender; hence, Hypothesis 1.1.3 is accepted.

Results Hypothesis 1.1.4: The SSDQ will demonstrate factorial invariance for secondary school stage.

Overview. Hypothesis 1.1.4 proposed that the a priori five factor structure of the SSDQ is invariant across the secondary schooling stages: i.e., early (Years 7 & 8 = Stage 4), middle (Years 9 & 10 = Stage 5), late (Years 11 & 12 = Stage 6).

Results. Results for invariance of secondary schooling stages are presented in Table 6.6. As described in Chapter 5, invariance is evaluated by the application of two multi-group CFA models (M1 and M2). The goodness of fit indices indicate an acceptable fit for the two models proposed. As above, the change in CFI values of the two models was used to evaluate the invariance. A change in CFI of less than +/- .01 is supportive of invariance (Cheung & Rensvold, 2002). The observed change in CFI between M1 and M2 was less than .01 (i.e., 0.006). Thus, the desirable minimal level of invariance (Cheung & Rensvold, 2002) is achieved for stage of secondary school.
Table 6.6
Summary of Goodness of Fit Statistics for Invariance Testing for the Science Self-Description Questionnaire (SSDQ) Across Secondary Schooling Stages

<table>
<thead>
<tr>
<th>Model</th>
<th>Model Description</th>
<th>$\chi^2$</th>
<th>df</th>
<th>CFI</th>
<th>TLI</th>
<th>RMSEA</th>
<th>90% CI for RMSEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 1</td>
<td>Completely free</td>
<td>720.58</td>
<td>480</td>
<td>.923</td>
<td>.908</td>
<td>.062</td>
<td>.053—.072</td>
</tr>
<tr>
<td>M 2</td>
<td>FL, IT = Invariant</td>
<td>777.64</td>
<td>520</td>
<td>.917</td>
<td>.909</td>
<td>.062</td>
<td>.053—.071</td>
</tr>
</tbody>
</table>

Note. $\chi^2$ = Chi Square, df = degrees of freedom, CFI = Comparative Fit Index, TLI = Tucker-Lewis Fit Index, RMSEA = Root Mean Square Error of Approximation, FL = Factor Loadings, IT = Intercepts.

**Conclusion.** The two proposed models demonstrate acceptable model fit statistics for a good fit. The minimal desirable level of invariance was evident for stage of secondary school. Therefore, Hypothesis 1.1.4 is accepted.

**Results for Hypotheses 1.2.1–1.2.2: Psychometric Assessment of the SMQ**

**Descriptive Statistics**

Basic descriptive statistics such as mean, standard deviation, skewness, and kurtosis for the SMQ are given in Table 6.7. Table 6.7 shows some evidence of moderate kurtosis and skewness. West, Finch, and Curran (1995) recommend that the maximum likelihood method of estimation is adequate when the absolute values of kurtosis and skewness are less than 7 and 2 respectively. For these data, all values were within these limits.

The results in Table 6.7 suggest that students’ Mastery Motivation means were greater than Intrinsic and Ego Motivation means. Means for all three types of motivation also increased across students’ stages, from stage 4 to stage 6.
Table 6.7
Descriptive Statistics for the Science Motivation Questionnaire (SMQ)

<table>
<thead>
<tr>
<th>Grouping Variable</th>
<th>Mastery</th>
<th>Intrinsic</th>
<th>Ego</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5.06</td>
<td>4.54</td>
<td>4.08</td>
</tr>
<tr>
<td>Male</td>
<td>4.88</td>
<td>4.55</td>
<td>4.04</td>
</tr>
<tr>
<td>Female</td>
<td>5.25</td>
<td>4.53</td>
<td>4.13</td>
</tr>
<tr>
<td>Stage 4</td>
<td>4.74</td>
<td>4.28</td>
<td>4.01</td>
</tr>
<tr>
<td>Stage 5</td>
<td>5.07</td>
<td>4.40</td>
<td>4.00</td>
</tr>
<tr>
<td>Stage 6</td>
<td>5.39</td>
<td>4.96</td>
<td>4.19</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1.17</td>
<td>1.50</td>
<td>1.62</td>
</tr>
<tr>
<td>Male</td>
<td>1.19</td>
<td>1.60</td>
<td>1.68</td>
</tr>
<tr>
<td>Female</td>
<td>1.15</td>
<td>1.40</td>
<td>1.56</td>
</tr>
<tr>
<td>Stage 4</td>
<td>1.27</td>
<td>1.56</td>
<td>2.81</td>
</tr>
<tr>
<td>Stage 5</td>
<td>1.16</td>
<td>1.50</td>
<td>1.58</td>
</tr>
<tr>
<td>Stage 6</td>
<td>1.07</td>
<td>1.44</td>
<td>1.69</td>
</tr>
<tr>
<td>Skewness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-1.26</td>
<td>-0.96</td>
<td>-0.49</td>
</tr>
<tr>
<td>Male</td>
<td>-1.09</td>
<td>-1.09</td>
<td>-0.35</td>
</tr>
<tr>
<td>Female</td>
<td>-1.43</td>
<td>-0.80</td>
<td>-0.64</td>
</tr>
<tr>
<td>Stage 4</td>
<td>-1.22</td>
<td>-0.69</td>
<td>-0.08</td>
</tr>
<tr>
<td>Stage 5</td>
<td>-1.33</td>
<td>-0.71</td>
<td>-0.42</td>
</tr>
<tr>
<td>Stage 6</td>
<td>-1.22</td>
<td>-1.43</td>
<td>-0.51</td>
</tr>
<tr>
<td>Kurtosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1.98</td>
<td>0.91</td>
<td>-0.54</td>
</tr>
<tr>
<td>Male</td>
<td>1.13</td>
<td>1.27</td>
<td>-0.89</td>
</tr>
<tr>
<td>Female</td>
<td>2.84</td>
<td>0.54</td>
<td>-0.19</td>
</tr>
<tr>
<td>Stage 4</td>
<td>1.36</td>
<td>-0.15</td>
<td>-0.66</td>
</tr>
<tr>
<td>Stage 5</td>
<td>2.10</td>
<td>0.17</td>
<td>-0.51</td>
</tr>
<tr>
<td>Stage 6</td>
<td>2.49</td>
<td>2.69</td>
<td>-0.71</td>
</tr>
</tbody>
</table>

Note. Stage 4 = Early Stage (Years 7 & 8), Stage 5 = Middle (Years 9 & 10), Stage 6 = Late Stage (Years 11 & 12)
Results Hypothesis 1.2.1: The Science Motivation Questionnaire (SMQ) will yield acceptable reliability estimates for the total sample, as well as for critical groups.

**Overview.** Hypothesis 1.2.1 proposes that the first-order a priori three factor (Mastery, Intrinsic, and Ego) of the SMQ is a reliable measurement scale for the total sample, as well as for the specific subgroups (gender, stage) of the total sample.

**Results.** Table 6.8 shows reliability estimates for the SMQ factors. The results of the reliability estimates for the three SMQ factors show acceptably reliable measures, with Cronbach’s Alpha coefficients in the range of .89 to .90 for the total sample. Acceptable measures of reliability were also obtained across the different subgroups of the SMQ (Aron & Aron, 2003), with alpha coefficients ranging from .80 to .94.

**Conclusion.** Hypothesis 1.2.1 is accepted, as the SMQ demonstrates reliable measures for the total sample, as well as for the specific subgroups of interest (i.e., stage, gender).

Table 6.8

*Reliability Estimates (Cronbach’s Alpha) for the Total Sample and Subgroups for the Science Motivation Questionnaire (SMQ)*

<table>
<thead>
<tr>
<th>Grouping categories</th>
<th>Mastery</th>
<th>Intrinsic</th>
<th>Ego</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>.90</td>
<td>.90</td>
<td>.89</td>
</tr>
<tr>
<td>Male/Female</td>
<td>.84/.77</td>
<td>.92/.91</td>
<td>.94/.94</td>
</tr>
<tr>
<td>Stage 4/5/6</td>
<td>.87/.85/.80</td>
<td>.91/.93/.90</td>
<td>.94/.94/.94</td>
</tr>
</tbody>
</table>

Results Hypothesis 1.2.2: The SMQ will yield acceptable overall model fit in confirmatory factor analysis.

**Overview.** Hypothesis 1.2.2 proposes that the a priori three factor structure of the SMQ will demonstrate acceptable overall model fit using confirmatory factor analysis.

**Results.** The chi square statistics in the model fit results for SMQ were $\chi^2 = 154.62$, df = 51, $p < .001$. As the p value was very low (less than .05), the results suggest a poor or unsatisfactory fit (see Chapter 5). However, importantly, the
overall model fit indices were acceptable (Marsh et al., 1996), with CFI = .958, TLI = .946, and RMSEA = .072, with a 90% confidence interval of 0.060–0.086.

Factor loadings and factor correlations are shown in Tables 6.9 and 6.10 respectively. Table 6.10 shows that every item loading in SMQ is statistically significant and substantial in size (ranging between .63 and .92).

Table 6.9

*Standardised Factor Loadings for the Science Motivation Questionnaire*

<table>
<thead>
<tr>
<th>Items</th>
<th>Mastery</th>
<th>Intrinsic</th>
<th>Ego</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.63</td>
<td>.83</td>
<td>.92</td>
</tr>
<tr>
<td>2</td>
<td>.76</td>
<td>.84</td>
<td>.80</td>
</tr>
<tr>
<td>3</td>
<td>.80</td>
<td>.81</td>
<td>.85</td>
</tr>
<tr>
<td>4</td>
<td>.73</td>
<td>.85</td>
<td>.91</td>
</tr>
</tbody>
</table>

* All factor loadings are significant at $p < .05$

Table 6.11 shows that the factor correlations ranged from 0.35 to 0.64 and are therefore distinguishable. The factor correlations between mastery and Intrinsic Motivation are significantly higher than those between mastery and Intrinsic Motivation, and Intrinsic and Ego Motivation. However, lower statistical correlations need not imply any weakness of the scale, as the factors are not necessarily correlated.

Table 6.10

*Factor Correlations of the Science Motivation Questionnaire*

<table>
<thead>
<tr>
<th></th>
<th>Mastery</th>
<th>Intrinsic</th>
<th>Ego</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mastery</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrinsic</td>
<td>.64</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Ego</td>
<td>.40</td>
<td>.35</td>
<td>1</td>
</tr>
</tbody>
</table>

* All correlations are significant at $p < .05$
Conclusion. According to the above results, a substantial degree of variance in the items is accounted for by the factor loadings of the respective factors. The model fit statistics also show a good fit. Thus, Hypothesis 1.2.2 is supported and the three factor model of SMQ (Figure 6.2) is accepted.

Results Hypotheses 1.2.3 and 1.2.4: Factorial Invariance Testing of the SMQ for Gender and Stage of Secondary School

Results Hypothesis 1.2.3: The SMQ will demonstrate factorial invariance for Gender.

Overview. Hypothesis 1.2.3 proposed that the a priori three factor structure of the SMQ is invariant across gender.

Results. Results for invariance of gender are given in Table 6.11. The proposed models show acceptable model fit statistics for a good fit. Based on the evaluation of two multi-group CFA models (M1 and M2), the change in CFI value of the two models was .01. Hence, a desirable minimal level of invariance was achieved (Cheung & Rensvold, 2002). Further, there is some overlap between the 90%
confidence intervals for the RMSEA of the two models, suggesting that the level of invariance was higher than the desirable minimal level (Bodkin-Andrews, Denson, et al., 2010; Byrne, 1998).

Table 6.11

*Summary of Goodness of Fit Statistics for Invariance Testing of the Science Motivation Questionnaire (SMQ) Across Gender*

<table>
<thead>
<tr>
<th>Model</th>
<th>Model Description</th>
<th>( \chi^2 )</th>
<th>df</th>
<th>CFI</th>
<th>TLI</th>
<th>RMSEA</th>
<th>90% CI for RMSEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 1</td>
<td>Completely free</td>
<td>212.61</td>
<td>102</td>
<td>.956</td>
<td>.943</td>
<td>.075</td>
<td>.061—.090</td>
</tr>
<tr>
<td>M 2</td>
<td>FL, IT = Invariant</td>
<td>249.68</td>
<td>114</td>
<td>.946</td>
<td>.938</td>
<td>.079</td>
<td>.066—.092</td>
</tr>
</tbody>
</table>

*Note.* \( \chi^2 \) = Chi Square, df = degrees of freedom, CFI = Comparative Fit Index, TLI = Tucker-Lewis Fit Index, RMSEA = Root Mean Square Error of Approximation, FL = Factor Loadings, IT = Intercepts.

Conclusion. The goodness of fit indices indicates a good fit for both models proposed. The minimal desirable level of invariance was evident for gender. Therefore, Hypothesis 1.2.3 is accepted.

Results Hypothesis 1.2.4: The SMQ will demonstrate factorial invariance for secondary school stage.

**Overview.** Hypothesis 1.2.4 proposed that the a priori three factor structure of the SMQ is invariant across the secondary schooling stages.

**Results.** Results for invariance for secondary schooling stages are given in Table 6.12. The proposed two models demonstrated an acceptable goodness of fit indices. Two multi-group CFA models (M1 and M2) show that the change in CFI value of the two models is less than .01 (i.e., 0.001). Thus, a desirable minimal level of invariance is achieved (Cheung & Rensvold, 2002). Moreover, there is some overlap between the 90% confidence intervals for the RMSEA of the two models, suggesting that the level of invariance is higher than the desirable minimal level (Bodkin-Andrews, Denson, et al., 2010; Byrne, 1998).
Table 6.12


<table>
<thead>
<tr>
<th>Model</th>
<th>Model Description</th>
<th>$\chi^2$</th>
<th>$df$</th>
<th>CFI</th>
<th>TLI</th>
<th>RMSEA</th>
<th>90% CI for RMSEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 1</td>
<td>Completely free</td>
<td>250.58</td>
<td>153</td>
<td>.955</td>
<td>.941</td>
<td>.070</td>
<td>.054—.086</td>
</tr>
<tr>
<td>M 2</td>
<td>FL, IT = Invariant</td>
<td>276.26</td>
<td>177</td>
<td>.954</td>
<td>.948</td>
<td>.066</td>
<td>.050—.081</td>
</tr>
</tbody>
</table>

Note. $\chi^2$ = Chi Square, $df$ = degrees of freedom, CFI = Comparative Fit Index, TLI = Tucker-Lewis Fit Index, RMSEA = Root Mean Square Error of Approximation, FL = Factor Loadings, IT = Intercepts.

**Conclusion.** The goodness of fit indices for the proposed models show an acceptable model fit. The minimal desirable level of invariance was evident for stage of secondary school. Therefore, Hypothesis 1.2.4 is accepted.

**Results for Hypotheses 1.3.1–1.3.4: Psychometric Assessment of the SAQ**

**Descriptive Statistics**

Basic descriptive statistics such as mean, standard deviation, skewness, and kurtosis for the SAQ are given in Table 6.13. Similarly to the descriptive statistics for the SSDQ and SMQ, the majority of values for the skewness and kurtosis are close to zero. There are minimal violations in multivariate normality, which are not likely to impact on the CFA procedures. Moreover, West, Finch, and Curran (1995) recommend that the maximum likelihood method of estimation is adequate when the absolute values of kurtosis and skewness are less than 7 and 2 respectively. Thus, for these data, all values are within these limits.

The results in Table 6.13 suggest that the students’ science aspiration means are greater than their career aspiration means in science. They also suggest that the science and career aspiration means of males are higher than those of females. Further, students’ science and career aspirations means increased across the stages from stage 4 to stage 6.
Table 6.13

*Descriptive Statistics for the Outcome Variables (SAQ, Teacher Ratings, and Student Ratings)*

<table>
<thead>
<tr>
<th>Grouping Variable</th>
<th>Science Aspirations</th>
<th>Career Aspirations</th>
<th>Student Ratings</th>
<th>Teacher Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3.68</td>
<td>3.57</td>
<td>3.56</td>
<td>3.65</td>
</tr>
<tr>
<td>Male</td>
<td>3.79</td>
<td>3.60</td>
<td>3.65</td>
<td>3.61</td>
</tr>
<tr>
<td>Female</td>
<td>3.59</td>
<td>3.53</td>
<td>3.58</td>
<td>3.76</td>
</tr>
<tr>
<td>Stage 4</td>
<td>3.43</td>
<td>3.30</td>
<td>3.54</td>
<td>3.66</td>
</tr>
<tr>
<td>Stage 5</td>
<td>3.87</td>
<td>3.74</td>
<td>3.63</td>
<td>3.66</td>
</tr>
<tr>
<td>Stage 6</td>
<td>4.65</td>
<td>4.63</td>
<td>3.67</td>
<td>3.82</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1.52</td>
<td>1.68</td>
<td>0.70</td>
<td>0.99</td>
</tr>
<tr>
<td>Male</td>
<td>1.49</td>
<td>1.64</td>
<td>0.70</td>
<td>0.92</td>
</tr>
<tr>
<td>Female</td>
<td>1.54</td>
<td>1.71</td>
<td>0.64</td>
<td>0.89</td>
</tr>
<tr>
<td>Stage 4</td>
<td>1.49</td>
<td>1.63</td>
<td>0.73</td>
<td>1.03</td>
</tr>
<tr>
<td>Stage 5</td>
<td>1.46</td>
<td>1.68</td>
<td>0.65</td>
<td>0.94</td>
</tr>
<tr>
<td>Stage 6</td>
<td>1.50</td>
<td>1.73</td>
<td>0.64</td>
<td>0.74</td>
</tr>
<tr>
<td><strong>Skewness</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-0.12</td>
<td>-0.04</td>
<td>0.08</td>
<td>-0.21</td>
</tr>
<tr>
<td>Male</td>
<td>-0.09</td>
<td>-0.06</td>
<td>-0.65</td>
<td>-0.60</td>
</tr>
<tr>
<td>Female</td>
<td>-0.12</td>
<td>-0.02</td>
<td>-0.11</td>
<td>-0.11</td>
</tr>
<tr>
<td>Stage 4</td>
<td>0.07</td>
<td>0.14</td>
<td>0.10</td>
<td>0.00</td>
</tr>
<tr>
<td>Stage 5</td>
<td>-0.24</td>
<td>-0.15</td>
<td>0.02</td>
<td>-0.33</td>
</tr>
<tr>
<td>Stage 6</td>
<td>-0.97</td>
<td>-0.88</td>
<td>-2.50</td>
<td>-0.73</td>
</tr>
<tr>
<td><strong>Kurtosis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-0.94</td>
<td>-1.22</td>
<td>0.00</td>
<td>1.15</td>
</tr>
<tr>
<td>Male</td>
<td>-1.03</td>
<td>-1.21</td>
<td>-0.61</td>
<td>0.94</td>
</tr>
<tr>
<td>Female</td>
<td>-0.89</td>
<td>-1.22</td>
<td>-0.26</td>
<td>0.28</td>
</tr>
<tr>
<td>Stage 4</td>
<td>-0.77</td>
<td>-1.04</td>
<td>0.28</td>
<td>0.12</td>
</tr>
<tr>
<td>Stage 5</td>
<td>-0.81</td>
<td>-1.33</td>
<td>-0.47</td>
<td>1.64</td>
</tr>
<tr>
<td>Stage 6</td>
<td>-0.29</td>
<td>-0.75</td>
<td>-0.82</td>
<td>0.07</td>
</tr>
</tbody>
</table>

*Note.* Stage 4 = Early Stage (Years 7 & 8), Stage 5 = Middle (Years 9 & 10), Stage 6 = Late Stage (Years 11 & 12)
Results Hypothesis 1.3.1: The Science Aspiration Questionnaire (SAQ) will yield acceptable reliability estimates for the total sample, as well as for critical groups.

**Overview.** Hypothesis 1.3.1 proposes that the first-order a priori two factor science and career aspirations of the SAQ are a reliable measurement scale for the total sample, as well as for the specific subgroups (stage, gender) of the total sample.

**Results.** Table 6.14 shows reliability estimates for the SAQ factors. The results of the reliability estimates for two factors of the SAQ show acceptably reliable measures, with Cronbach’s Alpha coefficients of .90. Acceptable measures of reliability were also obtained across the different subgroups of the SAQ (Aron & Aron, 2003), with alpha coefficients ranging from .89 to .97.

**Conclusion.** Hypothesis 1.3.1 is accepted, as the subscales of the SAQ demonstrate reliable measures for the total sample, as well as for the specific subgroups of interest (i.e., stage, gender).

<table>
<thead>
<tr>
<th>Grouping categories</th>
<th>Science Aspirations</th>
<th>Career Aspirations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>.90</td>
<td>.90</td>
</tr>
<tr>
<td>Male/Female</td>
<td>.89/.90</td>
<td>.94/.95</td>
</tr>
<tr>
<td>Stage 4/5/6</td>
<td>.90/.90/.89</td>
<td>.92/.95/.97</td>
</tr>
</tbody>
</table>

Results Hypothesis 1.3.2: The SAQ will yield acceptable overall model fit in confirmatory factor analysis.

**Overview.** Hypothesis 1.3.2 proposed that the a priori two factor structure of the SAQ with teacher and Student Ratings will demonstrate acceptable overall model fit in confirmatory factor analysis.

**Results.** The chi square statistics in the model fit results for SAQ were \( \chi^2 = 64.13, \text{ df} = 23, p < .001 \). As the p value is very low (less than .05) the results suggest a poor or unsatisfactory fit (see Chapter 5). However, the overall model fit indices are acceptable (Marsh, et al., 1996), with CFI = .983, TLI = .974, and RMSEA = .068, with a 90% confidence interval of 0.049–0.088.
Factor loadings and factor correlations are shown in Tables 6.15 and 6.16 respectively. Table 6.15 shows that every item loading in SAQ is statistically significant and substantial in size (ranging between .76 and .94).

Table 6.15

<table>
<thead>
<tr>
<th>Items</th>
<th>SA</th>
<th>CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.76</td>
<td>.93</td>
</tr>
<tr>
<td>2</td>
<td>.89</td>
<td>.88</td>
</tr>
<tr>
<td>3</td>
<td>.88</td>
<td>.94</td>
</tr>
<tr>
<td>4</td>
<td>.78</td>
<td>-</td>
</tr>
</tbody>
</table>

* All factor loadings are significant at \( p < .05 \)

**Note.** All parameter estimates are presented in completely standardized format. SA = Science Educational Aspirations, CA = Career Aspirations.

Table 6.16 shows that factor correlations range from 0.16 to 0.94. The factor correlation between science educational and career aspirations is significantly higher than the other factor correlations in the table, suggesting that these scales were measuring similar factors. Since these science educational and career aspirations were considered outcome variables in later analysis, both of them were included in evaluating relations using SEM path analysis (see Chapter 7).
Table 6.16

Factor Correlations of the Science Aspiration Questionnaire with Teacher and Student 
Ratings

<table>
<thead>
<tr>
<th></th>
<th>SA</th>
<th>CA</th>
<th>TR</th>
<th>SR</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA</td>
<td>1</td>
<td>.94</td>
<td>.19</td>
<td>.34</td>
</tr>
<tr>
<td>CA</td>
<td>.94</td>
<td>1</td>
<td>.16</td>
<td>.28</td>
</tr>
<tr>
<td>TR</td>
<td>.19</td>
<td>.16</td>
<td>1</td>
<td>.17</td>
</tr>
<tr>
<td>SR</td>
<td>.34</td>
<td>.28</td>
<td>.17</td>
<td>1</td>
</tr>
</tbody>
</table>

* All correlations are significant at $p < .05$

Note. All parameter estimates are presented in completely standardized format. SA = Science 
Educational Aspirations, CA = Career Aspirations, TR = Teacher Ratings, SR = Student Ratings.

**Conclusion.** According to the above results a substantial degree of variance in the items is accounted for by the factor loadings of the respective factors. The model fit statistics also show a good fit. Thus, Hypothesis 1.3.2 is supported and accepted. As the two SAQ factors are highly correlated only one factor can be used to represent the model. However, both of the factors remain in the model, as they are considered as outcome variables in further analysis.
Results Hypothesis 1.3.3: The SMQ will demonstrate factorial invariance for Gender.

Overview. Hypothesis 1.3.3 proposed that the a priori two factor structure of the SAQ with Teacher and Student Ratings is invariant across gender.

Results. Results for invariance for gender are given in Table 6.17. The goodness of fit indices demonstrate an acceptable model fit for both of the proposed models. Based on the evaluation of two multi-group CFA models (M1 and M2), the change in CFI value of the two models was less than .01 (i.e., 0.001). Hence, a desirable minimal level of invariance is achieved (Cheung & Rensvold, 2002). Further, there is some overlap between the 90% confidence intervals for the RMSEA of the two models, suggesting that a level of invariance is higher than the desirable minimal level (Bodkin-Andrews, Denson, et al., 2010; Byrne, 1998).
Table 6.17

Summary of Goodness of Fit Statistics for Invariance Testing for the Science Aspiration Questionnaire (SAQ) Across Gender

<table>
<thead>
<tr>
<th>Model</th>
<th>Model Description</th>
<th>$\chi^2$</th>
<th>df</th>
<th>CFI</th>
<th>TLI</th>
<th>RMSEA</th>
<th>90% CI for RMSEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 1</td>
<td>Completely free</td>
<td>94.63</td>
<td>46</td>
<td>.981</td>
<td>.970</td>
<td>.074</td>
<td>.053—.096</td>
</tr>
<tr>
<td>M 2</td>
<td>FL, IT = Invariant</td>
<td>98.96</td>
<td>53</td>
<td>.982</td>
<td>.975</td>
<td>.067</td>
<td>.046—.088</td>
</tr>
</tbody>
</table>

*Note. $\chi^2$ = Chi Square, df = degrees of freedom, CFI = Comparative Fit Index, TLI = Tucker-Lewis Fit Index, RMSEA = Root Mean Square Error of Approximation, FL = Factor Loadings, IT = Intercepts.*

**Conclusion.** Both of the proposed models above show a good fit, according to the model fit statistics. The minimal desirable level of invariance was evident for gender. Therefore, Hypothesis 1.3.3 is accepted.

**Results**

Hypothesis 1.3.4: The SMQ will demonstrate factorial invariance for secondary school stage.

**Overview.** Hypothesis 1.3.4 proposed that the a priori two factor structure of the SAQ with Teacher and Student Ratings is invariant across the secondary schooling stages.

**Results.** Results for invariance for secondary schooling stages are given in Table 6.18. The proposed models demonstrate a good fit. Two multi-group CFA models (M1 and M2) show that there is no change in the CFI value of the two models. Thus, a desirable minimal level of invariance is achieved (Cheung & Rensvold, 2002). Moreover, there is some overlap between the 90% confidence intervals for the RMSEA of the two models, suggesting that the level of invariance is higher than the desirable minimal level (Bodkin-Andrews, Denson, et al., 2010; Byrne, 1998).
Table 6.18


<table>
<thead>
<tr>
<th>Model</th>
<th>Model Description</th>
<th>$\chi^2$</th>
<th>df</th>
<th>CFI</th>
<th>TLI</th>
<th>RMSEA</th>
<th>90% CI for RMSEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 1</td>
<td>Completely free</td>
<td>137.33</td>
<td>69</td>
<td>.974</td>
<td>.959</td>
<td>.088</td>
<td>.066–.109</td>
</tr>
<tr>
<td>M 2</td>
<td>FL, IT = Invariant</td>
<td>151.32</td>
<td>83</td>
<td>.974</td>
<td>.966</td>
<td>.080</td>
<td>.059–.100</td>
</tr>
</tbody>
</table>

*Note. $\chi^2$ = Chi Square, df = degrees of freedom, CFI = Comparative Fit Index, TLI = Tucker-Lewis Fit Index, RMSEA = Root Mean Square Error of Approximation, FL = Factor Loadings, IT = Intercepts.*

Conclusion. The goodness of fit indices for the proposed models indicate a good fit. The minimal desirable level of invariance was evident for secondary school stage. Therefore, Hypothesis 1.3.4 is accepted.

Results for Research Question 1.4.1: Assessment Battery

Results Research Question 1.4.1: Structural Integrity of the Assessment Battery

Overview. Research Question 1.4.1 asks is there a factorial integrity in confirmatory factor analysis when all of the measurement scales (i.e., SSDQ, SMQ, and SAQ) are combined into one assessment battery. Specifically, factorial integrity is maintained when items load only on to those factors they are intended to load on to; that is, no cross-loadings emerge.

Results. The chi square statistics in the model fit results for the assessment battery were $\chi^2 = 1526.18$, df = 731, $p < .001$. As the $p$ value is very low (less than .05) the results suggest a poor or unsatisfactory fit (see Chapter 5). However, the overall model fit indices are acceptable (Marsh, et al., 1996) with CFI = .914, TLI = .903, and RMSEA = .053 with a 90% confidence interval of 0.049–0.057.

Conclusion. The model fit statistics show a good fit for the assessment battery. Hence, Research Question 1.4.1 is supported and there is a factorial integrity in the confirmatory factor analysis when all of the measurement scales (i.e., SSDQ, SMQ, and SAQ) are combined into one assessment battery. Thus, the individual scales utilised and the latent factors produced by the overall instrument (SSQ) can be differentiated, even when embedded within a multitude of other scales.
The path proposed for predicting outcome variables by predictive variables is shown in Figure 6.5.
Chapter Summary

The aims of study 1 were to assess the psychometric properties of the SSQ. Given the results shown in this chapter, Study 1 is accepted. Hence, all SSQ scales demonstrate strong and robust structural validity, excellent internal consistency reliability, and invariance across the grouping variables of interest (i.e., gender and secondary schooling stages). In addition, the SSQ fulfils the requirements of the integrity of the full assessment battery by indicating the strength of the overall instrument. Thus, the results of study 1 exhibit the sound psychometric properties of the SSQ by laying a good foundation between the network components.
CHAPTER 7

RESULTS OF STUDY 2: EXPLICATING THE SCIENCE MULTIDIMENSIONAL SELF-CONCEPTS, MOTIVATION, ASPIRATIONS, AND ACADEMIC ACHIEVEMENT OF AUSTRALIAN SECONDARY STUDENTS

Statistical models provide an efficient and convenient way of describing the latent structure underlying a set of observed variables (Byrne, 2012, p. 7).

Introduction

This chapter presents the results for Study 2; this is done in two parts. In the first part, Research Questions 2.1.1 to 2.4.3 are addressed, using descriptive statistics from SPSS and results from the MIMIC models to investigate the variation of students’ science self-concepts in different disciplines of science, science motivation (mastery, intrinsic, and ego orientations), science aspirations (science educational and career aspirations), and science achievement (Student Ratings and Teacher Ratings) across gender and year levels. In the second part, the remaining research questions (2.5.1 to 2.5.4) are addressed, using SEM path analyses to investigate relations between predictor variables (i.e., science self-concepts for research questions 2.5.1 and 2.5.2; and science motivation for research questions 2.5.3 and 2.5.4) and the outcome variables (i.e., science aspirations and science achievement).

The results from the MIMIC models are presented with their goodness of fit statistics, followed by the findings. The results from the SEM path analyses are presented in tables providing the beta coefficients (i.e., the standard regression coefficients of the path model). The magnitudes of the beta coefficients are useful in providing an effect size for the predictive power of variables. For example, if the beta value for a predictor variable such as year level has a magnitude of .4, this means that for every one standard deviation change in the predictor variable, there
will be a corresponding change in the outcome variable of .4 of a standard deviation change. While two different beta values may be different in magnitude, the differences are not always statistically significant. Hence, when one beta value is compared with another as a means for determining the relative strength of a predictor variable, such comparisons are done only after establishing that the differences are statistically significantly different.

Pearson correlations between the predictor variables and outcome variables are useful for detecting the possibility of suppression effects (see Chapter 5), and are included in Appendix E. Where the available evidence suggests the presence of a suppression effect, possible interpretations are given in Chapter 9.

Results for Research Questions 2.1.1–2.1.3: Explicating Science
Multidimensional Self-Concepts

Results Research Question 2.1.1: Differences on SSDQ Facets for the Total Sample

Overview. Research Question 2.1.1 sought to investigate to what extent students’ science self-concepts vary among the different science subject areas of science, biology, chemistry, earth and environmental science, and physics.

Results. As shown in Table 6.1, there was a small variation among the science self-concepts, ranging from a minimum of 3.84 for Physics Self-Concept to a maximum of 4.46 for General Science Self-Concept. A potential explanation for this finding is that many students had the opinion that physics is difficult, due to the struggle of comprehending many concepts, with some mathematical operations. Self-concepts for general science may be higher, as general science consists of subject matter from all four disciplines of science, which students may find easier, compared to pure physics, as these other disciplines include some easily understandable subject matter. While some of the differences are statistically significant according to the paired samples t-test, they range between a small and medium effect size, according to the Cohen’s $d$ effect size metric. This means that differences are in the vicinity of .4, or less, of a standard deviation.
Results Research Question 2.1.2: Differences on SSDQ Facets for the Sample across Gender

Overview. Research Question 2.1.2 sought to investigate to what extent students’ science self-concepts in different science subject areas vary across gender.

Results. Using the MIMIC model, where the science self-concept factors are regressed on year level and gender, the chi square results were $\chi^2 = 472.369, df = 205, p < .0001$. Although this small probability suggests that the model is not well represented by the data, as discussed in Chapter 5, the chi square statistic is sensitive to large sample sizes; hence the need for alternative fit statistics. The model fit statistics of RMSEA = 0.059, CFI = .920, and TLI = .902 suggest an acceptable fit. As shown in Table 7.1, significant beta coefficients are associated with General Science Self-Concepts, Chemistry Self-Concepts, and Physics Self-Concepts. Given the positive values of the beta coefficients, students’ General Science Self-Concepts, Chemistry Self-Concepts, and Physics Self-Concepts are, on average, greater in males than those for females. However, any variation is minimal, given that the maximum significant beta value is .187.

Table 7.1

<table>
<thead>
<tr>
<th></th>
<th>Beta coefficients</th>
<th>Variance explained by MIMIC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gender</td>
<td>Year Level</td>
</tr>
<tr>
<td>General Science</td>
<td>$\beta$</td>
<td>.127*</td>
</tr>
<tr>
<td>Biology</td>
<td>$\beta$</td>
<td>-.008</td>
</tr>
<tr>
<td>Chemistry</td>
<td>$\beta$</td>
<td>.148*</td>
</tr>
<tr>
<td>Earth &amp; Environmental</td>
<td>$\beta$</td>
<td>-.002</td>
</tr>
<tr>
<td>Physics</td>
<td>$\beta$</td>
<td>.187**</td>
</tr>
</tbody>
</table>

Note. All parameter estimates are presented in completely standardized format. $\beta$ = Beta Coefficient, * = All factor loadings are significant at $p < .05$, ** = All factor loadings are significant at $p < .01$. 
Results Research Question 2.1.3: Differences on SSDQ Facets for the Sample across Students in Different Year Levels

Overview. Research Question 2.1.3 sought to explore to what extent students’ science self-concepts in different science subject areas, vary across students’ secondary schooling year levels.

Results. As the variation of science self-concepts across school year levels was examined using the same model used for research Question 2.1.2, the same fit statistics apply here. Data pertaining to this research question are also shown in Table 7.1. For year level, significant beta values are associated with both General Science Self-Concepts and Biology Self-Concepts. Given the positive values of the beta coefficients, students’ self-concepts in general science and biology increase (albeit moderately) as year level increases.

Moreover, the MIMIC model was extended, to investigate whether there is an interaction effect between the variables of gender and year level, related to students’ science self-concepts. No evidence was shown of an interaction effect between these variables.

Conclusions for Research Questions 2.1.1–2.1.3: Explicating Science Multidimensional Self-Concepts

There is moderate variation among students’ science self-concepts in the different disciplines of science, with Physics Self-Concept being the lowest. Statistically significant differences (albeit small) were detected between male and female students for General Science Self-Concepts, Chemistry Self-Concepts, and Physics Self-Concepts whereby, according to MIMIC results, males displayed higher self-concepts than females in these domains. Some science self-concepts varied moderately across year level. Specifically, these results suggest that students’ self-concepts in general science and biology become stronger with age.
Results for Research Questions 2.2.1–2.2.3: Explicating Science Motivation

Results Research Question 2.2.1: Differences on SMQ Facets for the Total Sample

Overview. Research Question 2.1.1 posed the question, to what extent do students’ science motivations vary for the different motivation factors of mastery, intrinsic, and ego.

Results. As shown in Table 6.7, there is variation among the three different types of science motivation orientations. These range from a minimum of 4.08 for Ego Motivation to a maximum of 5.06 for Mastery Motivation. Given that Mastery Motivation is related to students’ ability, while Ego Motivation is associated with students’ competitiveness, this observed variation may suggest that students are more concerned with learning and achievement than they are with competing against others. While some of the differences between motivational types are statistically significant according to the paired sample t-test, they are medium in magnitude, according to the Cohen’s d effect size metric. This means that differences are in the vicinity of .4 of a standard deviation.

Results Research Question 2.2.2: Differences among SMQ Facets for the Sample across Gender

Overview. Research Question 2.2.2 asked to what extent do students’ science motivations of mastery, intrinsic, and ego orientations vary across gender.

Results. Using the MIMIC model, the chi square results were $\chi^2 = 191.509$, df = 78, $p < .0001$. The model fit statistics of RMSEA = 0.062, CFI = .956, and TLI = .942 suggest an acceptable fit. As shown in Table 7.2, when looking at the beta paths across gender, there are no significant beta coefficients for science motivation orientation in relation to mastery, intrinsic, and ego orientations, suggesting that these science motivations do not vary across gender.

Results Research Question 2.2.3: Differences among SMQ Facets for the Sample across Students in Different Year Levels

Overview. Research Question 2.2.3 sought to investigate to what extent the different motivation orientation types of mastery, intrinsic, and ego vary across students’ secondary schooling levels.
Results. Variation of science motivation across school year level was examined using the same model used for Research Question 2.2.2; hence, the same fit statistics apply here. As shown in Table 7.2, for year level, no significant values were associated with any of the science motivation types.

Table 7.2

<table>
<thead>
<tr>
<th></th>
<th>Beta coefficients</th>
<th>Variance explained by MIMIC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gender</td>
<td>Year Level</td>
</tr>
<tr>
<td>Mastery Motivation</td>
<td>β</td>
<td>-.060</td>
</tr>
<tr>
<td>Intrinsic Motivation</td>
<td>β</td>
<td>.050</td>
</tr>
<tr>
<td>Ego Motivation</td>
<td>β</td>
<td>.007</td>
</tr>
</tbody>
</table>

Note. All parameter estimates are presented in completely standardized format. β = Beta Coefficient, * = All factor loadings are significant at $p < .05$, ** = All factor loadings are significant at $p < .01$.

The MIMIC model was also used to test for any interaction effects between students’ gender and year levels on students’ science motivation (see Table 7.2). An interaction effect was detected between students’ gender and year level in mastery and ego orientations, but not in intrinsic orientation. The results of the interaction effects show that females in higher years demonstrate moderately higher science motivation in mastery orientation than males (Figure 7.1). However, in the lower years, males demonstrate moderately higher motivation in ego orientation than do females (Figure 7.2). As shown in Table 7.2, the interaction between gender and year level is minimal, with each of the significant beta values being less than .12.
**Figure 7.1.** Interaction effects between students’ gender and year level in mastery orientation.

**Figure 7.2.** Interaction effects between students’ gender and Year Level in ego orientation.
Conclusions for Research Questions 2.2.2–2.2.3: Explicating Science Motivation

There is moderate variation among students’ science motivation strengths in the three different orientations, in the descending order of mastery, intrinsic, and ego. While the results suggest interaction effects between gender and year for science motivation, the effects are minimal.

Results for Research Questions 2.3.1–2.4.3: Explicating Secondary Students’ Science Aspirations and Science Achievement

Results Research Question 2.3.1: Differences in Science Educational and Career Aspirations for the Total Sample

Overview. Research Question 2.3.1 sought to explore to what extent students’ Science Educational Aspirations may differ from their Science Career Aspirations for the total sample.

Results. Table 6.13 shows the mean for Science Educational Aspirations (3.68) to be moderately higher than the mean for Science Career Aspirations (3.57). A paired sample t-test was used to further explore the difference; the results reveal a significant difference between science educational and career aspirations, t(387) = 2.62, p < .001. Using the Cohen’s d effect size metric, this difference is small (d < .2). The results imply that students’ Science Educational Aspirations are slightly stronger than their Science Career Aspirations.

Results Research Question 2.3.2: Differences in Science Educational and Career Aspirations for the sample across Gender

Overview. Research Question 2.3.2 sought to examine to what extent secondary students’ aspirations (science educational and career) vary across gender.

Results. Using the MIMIC model, the chi square results were $\chi^2 = 74.791$, df = 38, p < .001. The model fit statistics of RMSEA = 0.050, CFI = .986, and TLI = .976 suggest an excellent fit. As shown in Table 7.3, looking at the beta paths for gender, there are no significant beta coefficients for both Science Educational Aspirations and career aspirations. This suggests that neither of the students’ science aspirations (science educational and career) vary across gender.
Results Research Question 2.3.3: Differences in Science Aspirations for the Sample across Students’ Year Levels

Overview. Research Question 2.3.3 asks to what extent secondary students’ aspirations (science educational and career) vary across levels of secondary schooling.

Results. Variation in science aspirations across school year levels was examined using the same model used for Research Question 2.3.2; hence, the same fit statistics apply here. Data pertaining to this Research Question are also shown in Table 7.3. Significance is shown both for Science Educational Aspirations and for career aspirations in science, across year level. Given the positive values of the beta coefficients, students’ science educational and career aspirations increase as year level increases. However, this association is small, given that the beta values associated with year level for both Science Educational Aspirations and career aspirations are moderate and approximately equal (.223 and .212 respectively).

Table 7.3
Variance Explained by the MIMIC Model of Outcome Variables (Aspirations) Across Gender and Year

<table>
<thead>
<tr>
<th></th>
<th>Beta coefficients</th>
<th>Variance explained by MIMIC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gender</td>
<td>Year</td>
</tr>
<tr>
<td>Science Educational Aspirations</td>
<td>β</td>
<td>.095</td>
</tr>
<tr>
<td>Science Career Aspirations</td>
<td>β</td>
<td>.048</td>
</tr>
</tbody>
</table>

Note. All parameter estimates are presented in completely standardized format. β = Beta Coefficient, * = All factor loadings are significant at p < .05, ** = All factor loadings are significant at p < .01.
Results Research Question 2.4.1: Differences on Science Achievement for the Total Sample

**Overview.** Research question 2.4.1 sought to examine to what extent students’ science achievements vary, according to teacher and Student Ratings.

**Results.** While the mean for teachers’ ratings of students (3.65) was moderately higher than the mean for students’ ratings of their performance (3.56), a paired sample t-test was used to explore the difference in ratings further. A non-significant difference was revealed, t(103) = 3.54, p = .160.

Results Research Question 2.4.2: Differences on Science Achievement for the Total Sample across Gender

**Overview.** Research Question 2.4.2 sought to examine to what extent students’ science achievements based on teacher and Student Ratings vary across gender.

**Results.** Variation in science achievement across students’ gender was examined using the same model used for Research Question 2.3.2: hence, the same acceptable fit statistics apply here. As shown in Table 7.4, there are no significant beta coefficients for student and Teacher Ratings across gender, suggesting that students’ science achievement does not vary across gender.

Table 7.4

*Variance Explained by the MIMIC Model of Outcome Variables (Achievement) Across Gender and Year*

<table>
<thead>
<tr>
<th></th>
<th>Beta coefficients</th>
<th>Variance explained by MIMIC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gender</td>
<td>Year</td>
</tr>
<tr>
<td>Student Ratings</td>
<td>$\beta$</td>
<td>.052</td>
</tr>
<tr>
<td>Teacher Ratings</td>
<td>$\beta$</td>
<td>-.040</td>
</tr>
</tbody>
</table>

*Note.* All parameter estimates are presented in completely standardized format. $\beta =$ Beta Coefficient, * = All factor loadings are significant at $p < .05$, ** = All factor loadings are significant at $p < .01$. 
Results Research Question 2.4.3: Differences on Science Achievement for the Sample across Students’ Year Levels

Overview. Research Question 2.4.3 sought to investigate to what extent students’ science achievements based on teacher and Student Ratings vary across students’ year levels of secondary schooling.

Results. Variation of science achievement across students’ year levels was examined using the same model used for Research Question 2.3.2; hence, the same fit statistics apply here. According to the data shown in Table 7.3, there are no significant beta coefficients for student and Teacher Ratings across students’ year levels. This suggests that students’ science achievement does not vary across year level.

Moreover, the MIMIC model was extended to investigate whether there was an interaction effect between students’ gender and year level related to students’ science aspirations and achievement. No evidence of an interaction between students’ gender and year level in students’ science aspirations (science educational and career aspirations) and achievement (Student Ratings and Teacher Ratings) was shown.

Conclusions for Research Questions 2.3.1–2.4.3: Explicating Secondary Students’ Science Aspirations and Science Achievement

For this sample, there is no evidence to suggest that students’ science educational and career aspirations vary across gender. However, students’ science educational and career aspirations increase moderately as year level of secondary schooling increases. With respect to student achievement in science, on average, teachers rate students only moderately higher than students rate themselves. However, there is no difference in students’ achievement in science (as measured by both students and Teacher Ratings) across gender and year levels of secondary students’ schooling.

Results for Research Questions 2.5.1–2.5.2: Relations of Students’ Science Self-Concepts with Science Aspirations and Science Achievement

The results for each of these Research Questions are presented in two steps. In the first step, the proposed SEM model (Model 1) investigates the degree to which
students’ gender and age serve as predictor variables for the outcome variables of science aspirations (i.e., science educational and career aspirations) for Research Question 2.5.1 and science achievement (based on student and Teacher Ratings) for Research Question 2.5.2. In the second step, an SEM model (Model 2) is developed by adding the additional predictor variables of science self-concepts to students’ gender and year level, to predict the outcome variables. In essence, this is a nested model. The model fit information and the beta values associated with the predictor variables were used to evaluate and interpret the strength of the relations in the path analyses.

**Results Research Question 2.5.1: Relations of Students’ Science Self-Concepts with Science Aspirations**

**Overview.** Research Question 2.5.1 posed the question whether students’ science self-concepts can predict Science Educational Aspirations and career aspirations.

**Results.** The proposed nested models are schematically represented in Figures 7.3 and 7.4. Using the SEM Model 1, where the outcome variables are regressed on year level and gender, the chi square results were $\chi^2 = 1182.900$, $df = 413$, $p < .0001$. The model fit statistics of RMSEA = 0.070, CFI = .877, and TLI = .862 do suggest a poor fit. The corresponding beta coefficients for gender and year level, and amount of total variance explained, are provided in Table 7.4.
Figure 7.3. SEM structural model for gender, year level, and science self-concepts over students’ science aspirations and achievement in science

Note. SA = Science Educational Aspirations CA = Career Aspirations, TR = Teacher Ratings, SR = Student Ratings, GN = Gender, YR = Year, GS = General Science, BG = Biology, CH = Chemistry, EE = Earth & Environmental Science, PH = Physics

As shown in Table 7.5, the total variances explained by gender and year level for science educational and career aspirations for Model 1 were 5.40% and 4.70% respectively. For year level, significant beta values are associated with students’ science educational and career aspirations. Given that there were no significant beta coefficients for gender, it is a predictor neither of students’ Science Educational Aspirations nor of their career aspirations.
Table 7.5

*Standardised Predictive Paths and Total Variance Explained for the Structural Equation Model for Gender and Year in Predicting Students’ Career Aspirations and Science Achievement*

<table>
<thead>
<tr>
<th></th>
<th>Beta coefficients and correlations</th>
<th>Variance explained by SEM (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gender</td>
<td>Year Level</td>
</tr>
<tr>
<td>Science Educational Aspirations</td>
<td>$\beta$</td>
<td>.09</td>
</tr>
<tr>
<td>Science Career Aspirations</td>
<td>$\beta$</td>
<td>.05</td>
</tr>
<tr>
<td>Teacher Ratings</td>
<td>$\beta$</td>
<td>-.04</td>
</tr>
<tr>
<td>Student Ratings</td>
<td>$\beta$</td>
<td>.05</td>
</tr>
</tbody>
</table>

*Note.* All parameter estimates are presented in completely standardized format. $\beta$ = Beta Coefficient, * = All factor loadings are significant at $p < .05$, ** = All factor loadings are significant at $p < .01$.

In Model 2, the predictor variables of self-concepts in general science, biology, chemistry, earth and environmental science, and physics, are added to students’ gender and year level. The outcome variables of students’ Science Educational Aspirations, career aspirations in science, teacher ratings, and student ratings remain the same. The proposed model is represented in Figure 7.4.
For Model 2, where the outcome variables are regressed on year level, gender, and the students’ science self-concepts, the chi-square results were $\chi^2 = 1182.900$, $df = 413$, $p < .0001$. The model fit statistics of RMSEA = 0.057, CFI = .922, and TLI = .908 do suggest an acceptable fit. Further, a chi-square ($\chi^2$) difference test was performed on the above two models. The chi-square ($\chi^2$) differences and degrees of freedom ($df$) between Model 1 and Model 2 were 304.41 and 20 respectively. Based on these differences, the Chi-square difference test was significant ($p < .000001$), suggesting that Model 2 is a better representation of the data than Model 1.

As shown in Table 7.6, the total variance explained in the Science Educational Aspirations by the inclusion of additional predictor variables was 39.30% (For Model 1, it was only 5.4%; see Table 7.5). The significant predictor
variables in this path are Year Level, Biology Self-Concepts, and Physics Self-Concepts. As shown in Table 7.6, the total variance explained in career aspirations by the inclusion of additional predictor variables is 28.90%. (For Model 1, it was only 4.7%; see Table 7.5.) Again, the significant predictor variables in this path are Year Level, Biology Self-Concepts, and Physics Self-Concepts. Year Level has the least predictive power.

Table 7.6

Standardised Predictive Paths and Total Variance Explained for the Structural Equation Model of Gender, Year, and Science Self-Concepts for Predicting Students’ Science Educational Aspirations, Career Aspirations, Teacher Ratings and Student Ratings

<table>
<thead>
<tr>
<th>Beta Coefficients</th>
<th>Variance explained by SEM (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GN</td>
</tr>
<tr>
<td>SA</td>
<td>.02</td>
</tr>
<tr>
<td>CA</td>
<td>-.01</td>
</tr>
<tr>
<td>TR</td>
<td>-.06</td>
</tr>
<tr>
<td>SR</td>
<td>-.03</td>
</tr>
</tbody>
</table>

Note. All parameter estimates are presented in completely standardized format. \( \beta \) = Beta Coefficient, * = All factor loadings are significant at \( p < .05 \), ** = All factor loadings are significant at \( p < .01 \). Of the SSDQ self-concept factors, SA = Science Educational Aspirations, CA = Career Aspirations, TR = Teacher Ratings, SR = Student Ratings, GN = Gender, YR = Year, GS = General Science, BG = Biology, CH = Chemistry, EE = Earth & Environmental Science, PH = Physics.

Results Research Question 2.5.2: Relations of students’ Science Self-Concepts with Science Achievement

Overview. Research Question 2.5.2 posed whether students’ science self-concepts can predict achievement in science.
Results. This research question was addressed using the same nested models represented in Figures 7.3 (Model 1) and 7.4 (Model 2), though the focus of this discussion is on teacher ratings and student ratings. Thus, the same model fit statistics reported for Research Question 2.5.1 apply here. The corresponding beta coefficients and total variance explained for the path models are provided in Tables 7.5 and 7.6.

As mentioned in relation to Research Question 2.5.1, the model fit statistics suggest a poor model fit for the proposed path in Model 1. The data in Table 7.5 reveal that neither gender nor year levels were predictors of students’ achievement in science, as represented by both teacher ratings and student ratings.

As previously mentioned, the model fit statistics suggest an acceptable fit for Model 2, suggesting that the inclusion of additional predictor variables explains a greater proportion of variance in the outcome variables. The data in Table 7.5 reveal that the amount of total variance explained in Teacher Ratings is 12.20%. (For Model 1, it was less than 1%; see Table 7.5.) The students’ Biology Self-Concept was the only predictor variable that had a significant beta value. The total variance in student ratings explained by the predictive path is 50.50%. (For Model 1, it was less than 1%; see Table 7.5.) According to the results, students’ General Science Self-Concept was the only significant predictor in this path, with a beta value of .62.

Conclusions for Research Question 2.5.1 - 2.5.2: Relations of Students’ Science Self-Concepts with Science Aspirations and Achievement

Students’ Year Level, Biology Self-Concept, and Physics Self-Concept are significant predictors of students’ Science Educational and Career Aspirations. Statistically, of these three predictor variables, Physics Self-Concept was the strongest predictor of students’ Science Educational and Career Aspirations. Students’ Biology Self-Concept was a moderate predictor of students’ achievement, based on the Teacher Ratings, while students’ General Science Self-Concept was the only statistically significant predictor of students’ achievement, based on Student Ratings.
Results for Research Questions 2.5.3 – 2.5.4: Relations of Students’ Science Motivation with Science Aspirations and Science Achievement

The results for these Research Questions are also presented in two steps, and parallel the results for Research Questions 2.5.1 and 2.5.2. In the first step, the proposed SEM model (Model 1) investigates the degree to which students’ gender and age serve as predictor variables for the outcome variables of science aspirations (i.e., science educational and career aspirations) for Research Question 2.5.3, and science achievement (based on student and Teacher Ratings) for Research Question 2.5.4. In the second step, an SEM model (Model 2) was developed by adding the additional predictor variables of science motivation (mastery, intrinsic, and ego orientations) to students’ gender and year level, to predict the outcome variables (i.e., science aspirations and science achievement). This in essence, is a nested model. The model fit information and the beta values associated with the predictor variables were used to evaluate and interpret the strength of the relation in path analyses.

Results Research Question 2.5.3: Relations of Students’ Science Motivation with Science Aspirations

Overview. Research Question 2.5.3 posed whether students’ science motivation can predict science aspirations.

Results. The proposed nested models are schematically represented in Figures 7.5 (Model 1) and 7.6 (Model 2). For Model 1, where the outcome variables were regressed on year level and gender, the chi square results were $\chi^2 = 547.325$, $df = 216$, $p < .0001$. The model fit statistics of RMSEA = 0.063, CFI = .933, and TLI = .920 suggest an acceptable fit. The corresponding beta coefficients for gender and year level, and amount of total variance explained, are provided in Table 7.4.
The first part of this research questions uses the results given for Research Question 2.5.1. Accordingly, for Model 1 (see Figure 7.5), significant beta values are associated with students’ science educational and career aspirations (see Table 7.4). Given that there are no significant beta coefficients for gender, it is neither a predictor of students’ Science Educational Aspirations nor of career aspirations.

For Model 2, the predictive variables of Mastery, Intrinsic, and Ego Orientations in science motivation were added to students’ gender and year level (see Figure 7.6). The outcome variables of students’ Science Educational Aspirations, Career Aspirations in science, teacher Ratings, and student Ratings, remain the same.

Figure 7.5. SEM Path for gender, year, and science motivation over science aspirations and students’ achievement in science

Note. SA = Science Educational Aspirations, CA = Career Aspirations, TR = Teacher Ratings, SR = Student Ratings, GN = Gender, YR = Year, MM = Mastery Motivation, IM = Intrinsic Motivation, EM = Ego Motivation.
Figure 7.6. SEM Path for gender, year, and science motivation over science educational aspirations, career aspirations, and students’ achievement in science.

Note. SA = Science educational Aspirations, CA = Career Aspirations, TR = Teacher Ratings, SR = Student Ratings, GN = Gender, YR = Year, MM = Mastery Motivation, IM = Intrinsic Motivation, EM = Ego Motivation.

In Model 2, where the outcome variables were regressed on all the predictor variables, the chi square results were $\chi^2 = 392.448$, $df = 204$ $p < .0001$. The model fit statistics of RMSEA = 0.063, CFI = .964, and TLI = .956 suggest an excellent fit. As with Research Questions 2.5.1 and 2.5.2, the chi-square ($\chi^2$) difference test was performed on the above two models. The chi-square ($\chi^2$) differences and degrees of freedom ($df$) between Model 1 and Model 2 were 154.887 and 12 respectively. Based on these differences, the chi-square difference test was significant ($p < .000001$), suggesting that Model 2 is a better representation of the data than Model 1.

As given in Table 7.7, the total variance explained in the Science Educational Aspirations by the inclusion of additional predictor variables is 37.60% (For Model 1, it was only 5.4%, see Table 7.5). The total explained variance in the Science Career Aspirations by the predictive variables is 31.10% (For Model 1, it was only 4.7%, see Table 7.5.) The significant predictor variables in these paths, both for Science Educational Aspirations and career aspirations, are year level and Intrinsic Motivation. For both types of aspirations the beta values associated with year level are each significantly smaller than the beta values associated with Intrinsic
Motivation. Hence, students’ Intrinsic Motivation was the stronger predictor of students’ Science Educational Aspirations and career aspirations.

Table 7.7

*Standardised Predictive Paths and Total Variance Explained for the SEM for Gender and Year with Science Motivation for Predicting Students’ Science Educational Aspirations, Career Aspirations, Teacher Ratings, and Student Ratings*

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>Year</th>
<th>Mastery</th>
<th>Intrinsic</th>
<th>Ego</th>
<th>Variance explained by SEM (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Aspirations</td>
<td>\beta</td>
<td>.08</td>
<td>.18**</td>
<td>.07</td>
<td>.54**</td>
<td>.00</td>
</tr>
<tr>
<td>Career Aspirations</td>
<td>\beta</td>
<td>.03</td>
<td>.18**</td>
<td>.08</td>
<td>.48**</td>
<td>-.02</td>
</tr>
<tr>
<td>Teacher Ratings</td>
<td>\beta</td>
<td>-.04</td>
<td>.00</td>
<td>.09</td>
<td>.10</td>
<td>.00</td>
</tr>
<tr>
<td>Student Ratings</td>
<td>\beta</td>
<td>.05</td>
<td>.04</td>
<td>.17*</td>
<td>.24**</td>
<td>.11*</td>
</tr>
</tbody>
</table>

*Note. All parameter estimates are presented in completely standardized format.*

* = All factor loadings are significant at \( p < .05 \),

** = All factor loadings are significant at \( p < .01 \), \( \beta \) = Beta coefficients.

Results Research Question 2.5.4: Relations of Students’ Science Motivation with Science Achievement

**Overview.** Research Question 2.5.4 posed whether students’ science motivation can predict achievement in science.
**Results.** This research question was addressed using the same nested models represented in Figures 7.5 (Model 1) and 7.6 (Model 2), though the focus of this discussion is on Teacher Ratings and Student Ratings. Thus, the same model fit statistics reported for Research Question 2.5.3 apply here. The corresponding beta coefficients and total variance explained for the path models are provided in Tables 7.5 and 7.7.

As mentioned in discussion of Research Question 2.5.3, the model fit statistics suggest an acceptable fit for the proposed path in Model 1. The data in Table 7.5 reveal that neither gender nor year level is a predictors of students’ achievement in science as represented both by Teacher Ratings and Student Ratings.

As previously mentioned in Research Question 2.5.3, the model fit statistics suggested an excellent fit for Model 2, suggesting that the inclusion of additional predictor variables explained a greater proportion of variance in the outcome variables of Teacher Ratings and Student Ratings. The data in Table 7.7 reveal that the amount of total variance explained in Student Ratings is 18.30%. (For Model 1, it was less than 1%; see Table 7.5) Significant beta values are associated with all three motivation orientations for Teacher Ratings.

**Conclusions for Research Question 2.5.3 - 2.5.4: Relations of Students’ Science Motivation with Science Aspirations and Achievement**

Students’ year level and Intrinsic Motivation were predictors of students’ educational and career aspirations in science. Intrinsic Motivation was a stronger predictor than year level for both aspiration types.

The students’ Mastery, Intrinsic, and Ego Motivations were significant predictors of students’ achievement based on Student Ratings. Students’ achievement based on Teacher Ratings was not predicted by any of the predictor variables in the proposed paths.
Chapter Summary

Students’ self-concepts for the domains of general science, chemistry, and physics were moderately stronger for males than for females. Students’ self-concepts in general science and biology became stronger with age. Females in higher years demonstrate moderately higher science motivation in mastery orientation than do males. However, in the lower years, males demonstrate moderately higher motivation in ego orientation than do females. The strength of students’ science educational and career aspirations does not vary across gender, while their science educational and career aspirations increase as year level of secondary schooling increases. There is no difference in students’ achievement in science across gender and year levels of secondary schooling.

Of the predictor factors, students’ Year Level, Biology Self-Concepts, and Physics Self-Concepts were significant predictors of students’ science educational and career aspirations. The students’ Physics Self-Concepts factor was the strongest predictor out of the above three predictor variables. Students’ Biology Self-Concept was a significant predictor of students’ achievement based on teacher ratings, while students’ General Science Self-Concept was a significant predictor of students’ achievement based on Student Ratings.

Intrinsic Motivation and year level were significant predictors of students’ science educational and career aspirations. Of the above two predictor variables, students’ Intrinsic Motivation was stronger than schooling year level in the predictive paths. Mastery, Intrinsic, and Ego Motivation were significant predictors of student ratings on students’ achievement in science.
CHAPTER 8

RESULTS OF STUDY 3: A QUALITATIVE EXAMINATION OF THE ASSOCIATIONS BETWEEN AUSTRALIAN SECONDARY STUDENTS’ SCIENCE SELF CONCEPTS, MOTIVATION, ASPIRATIONS, AND ACHIEVEMENT

Introduction

This chapter presents the results for the qualitative component of this research (Study 3). The aims of Study 3 were to explore students’ and teachers’ perceptions of the: (1) causes of the decline in student enrolments in high school science; (2) factors influencing students’ decision-making processes when deciding whether or not to pursue science subjects at school; and (3) factors influencing students’ post-schooling options. Teachers and students from two schools participated in the qualitative component of the present investigation. The students interviewed comprised those whose results were in the top 10% and bottom 10% of responses on the composite total science attitude score (i.e., the average of total self-concept, motivation, and aspirations scores), based on answers to the student questionnaire (see Chapter 5).

The results for each research question in Study 3 are presented, on the basis of content and thematic analyses of students’ and teachers’ responses. The results for this chapter are presented under the two major headings. Firstly, findings from the student focus groups are presented, followed by findings from the teacher interviews. For each research question, the main findings are presented, along with quotes from the interviewees, and are grouped according to the major themes identified. For each quote, an appropriate student identification number with school year, or teacher identification number, is provided within square brackets. Finally, conclusions are presented for each research question.
Findings from the Student Focus Groups

Research Question 3.1.1: What influences secondary students’ decisions to undertake science subjects at school?

Overview. Research Question 3.1.1 sought to identify the factors influencing secondary students’ decisions to study science subjects at school. Several themes emerged, and are discussed in the paragraphs that follow.

Enjoyment of the subject. Focus group data revealed that students’ level of enjoyment of science influenced their decision to undertake and continue science as an elective. As expected, students with high science self-concepts perceived science as enjoyable and fun, as illustrated by the following comments.

*Science is better than most of the other subjects. Because like it’s more fun to continue things instead of doing boring work* [St24, Year 7].

*I just find it really interesting most of the times to see how different chemicals can react, how physics works, how a lot of aspects of science like work. Probably I will go to the University of New South Wales to study science* [St2, Year 10].

In comparison, most of the students with low science self-concepts had the opinion that science was not for them and was boring. They reported disliking the subject as they were not interested, for a number of different reasons, which are discussed later in this chapter. Some of the students’ responses are given below.

*I hate science altogether. I tell others all of the bad things about science. If they have a choice I’ll tell them not to do it* [St19, Year 7].

*I don’t like science. It’s kind of boring. I wouldn’t study it* [St58, Year 9].

Level of difficulty of the subject. Consistently, students with high science self-concepts considered science an easy subject, and they liked learning science. They also reported understanding scientific concepts and principles. For example, one student claimed that “science is really easy; I would recommend it to others”
Others spoke of their enjoyment of the subject and their wish to pursue it further, as it enabled them to access knowledge that was unknown to others. This was clearly evidenced in the following quote, from a Year 10 student: “I would like to extend my studies in physics and chemistry. Just understanding certain things that other people don’t. Science is easy to understand” [St1].

In contrast, students with low science self-concepts typically found science difficult. They said that science was difficult for them to understand, especially when the teacher explained the lessons too quickly. These students also found science more challenging compared to subjects like art, English, and music. In particular, students experienced difficulty in understanding abstract concepts like atomic structure and calculations. For example:

*Science is pretty hard. Teacher explains like too fast to me, then next lesson what we learn is something different. I don’t really get it into my head. Other subjects are good for me. I don’t like the subject [St21, Year 8].

*Work is getting really confusing. Actually, I struggle with chemistry theory. I do a lot better in other subjects—Arts, English—than science [St52, Year 12].

**Experimental nature of the subject.** Students with high science self-concepts and those with low science self-concepts alike enjoyed and appreciated experiments and practical work in science. For example, one student commented: “Explosions ... It’s fun. Science is a very important subject” [St17, Year 8]. Students also stated that performing experiments was fun and that they did not have to remember much when doing the experiments, compared to learning the theory of the subject. For example, a student with high science self-concept expressed that “Practicals are more hands on and easier. Don’t have to remember as much. I’ll recommend it to my siblings” [St7, Year 11].
Similarly, students with low science self-concept reported that:

*I like doing experiments. It’s interesting ... In primary schools we couldn’t do experiments, we just learn, but in high school we can do experiments [St51, Year 7].*

*When it comes to the text, I find some critiques. Sometimes, even I study for it, I still don’t get good marks but I find it interesting with the experiments [St62, Year 10].*

**Relevance of the subject.** Consistently, students with high self-concepts found, learning science a meaningful process as they could relate many of the concepts and principles to their day-to-day life. For example:

*Science is a very important subject. Science helps with curing and giving medicine ...Without science half of us are dead [St17, Year 8].*

*Personally, I like physics the most. Just learning about how sitting in a chair has like more meaning than just sitting on a chair. I plan to do physics and chemistry [St49, Year 10].*

Some students with low science self-concepts had the opinion that science learning is not meaningful. For example, a student from Year 8 stated “I don’t do much in the class. Because I don’t find it a useful subject” [St49, Year 10]. However, some low self-concept students also believed that science was an important subject for their day-to-day life. For example:

*I would rather study physics than any other science subject because it is more important. I say it’s one of the pretty important things to learn [St38, Year 10].*

*To understand the world around you, science is important. I would definitely recommend people to take science. It’s interesting. It’s applicable to everybody [St11, Year 11].*
**Teacher characteristics.** Students with both high and low science self-concepts reported that they liked passionate and kind science teachers who explained the subject matter very well, as evidenced by the following quotes:

Expressions from high self-concept students:

*My teacher loves me. Because I understand science a bit more. It’s important for the teacher to be kind, humorous, and fun.* [St16 Year 8].

*In biology we have a really good teacher. She explains the work well. She actually gets into the work. And when she is away or on leave we have this really boring sub, and she can’t teach well. She just puts up overheads…. She doesn’t actually teach us. So we don’t actually learn things* [St6, Year 11].

Expressions from low self-concept students:

*We have to be passionate about the subject as well as the teacher being passionate about it* [St60, Year 10].

*I think when we learn they should make it more interesting and we should do more like assigned practicals using a Bunsen burner* [St60, Year 10].

Some low science self-concept students also reported that they experienced difficulties in science when they felt teachers did not explain the subject matter clearly. This is illustrated by the following quote:

*I think science would be much better if the teacher is explaining everything more clearly to us, like they don’t exactly teach like … I don’t know it’s very hard to understand that … we just go study ourselves and understand it… teachers should have better explanations* [St61, Year 10].
One student reported that their science teacher did not seem to like them: “My science teacher hates me a lot. I don’t do much in the class. Because I don’t find it a useful subject” [St19, Year 8].

**Content.** The subject content is a critical issue in students’ experience of studying science at the high school level. Many students emphasised their view that they had to do more calculations in chemistry and physics, compared to the other two science disciplines. Given that many students find performing calculations difficult, they found this part of science the most challenging. Students also emphasised that in biology and other science areas, they had too much to remember and that this sometimes confused them. For example:

Expressions from high self-concept students:

> It’s like a lot of stuff in the body has the same name as something else. It’s the kind of thing that really gets confusing. Biology is too hard to comprehend with all the terms and a lot of them are the same [St1, Year 10].

> I don’t like physics, but it’s important. It helps to understand the universe. ... It’s hard because of maths [St5, Year 11].

Expressions from low self-concept students:

> Chemistry and physics are the most difficult parts of the subject. I usually score better in tests relating to earth and environmental science [St34, Year 9].

> It’s really interesting but a lot of content, a lot to remember, interesting about the body and things. Work is getting really confusing [St52, Year 12].

**Different disciplines of science.** Students’ interests varied in different areas of science. Some students reported liking biology, as they preferred to understand more about the human body, whilst others liked chemistry, because they were able to do more interesting experiments with chemicals. Some students claimed that they
liked physics very much, as they could learn about forces, mechanics, and motion. A few students also reported liking earth and environmental science, as they thought it was easy and more relevant to their life. Many students with high science self-concepts enjoyed chemistry and physics compared to biology and earth and environmental science, as demonstrated by the following quote:

\[ I \text{ do chemistry and biology. I actually enjoy chemistry and find it very interesting. I do biology too but I don’t like it very much, too much theory. I don’t like memorising things. I am a calculation person [St41, Year 11].} \]

Conversely, many students with low science self-concepts preferred and enjoyed biology, earth, and environmental science more than chemistry and physics, as they found the latter subjects too difficult. For example, as stated by a Year 12 student identified as having a low science self-concept:

\[ \text{Like in junior school I really liked biology maybe due to the teacher or more interesting stuff. All the other stuff, all that chemistry and physics stuff I never enjoyed. I find biology easier compared to chemistry. Because in chemistry you have to use numbers a lot for formulae, numbers and stuff I am not good at that [St53, Year 12].} \]

**Conclusion.** Significant factors that influence secondary students’ decisions to undertake science subjects at school include: being enthusiastic about science, enjoying the subject, performing experiments, understanding the subject, and having effective and passionate teachers. Students with high self-concepts perceive science as an interesting subject, while students with low self-concepts perceive science as a boring subject. Students with low self-concept reported that some of the reasons they did not like science were: the lack of practical experiments, their poor understanding of science concepts and principles, the perceived irrelevance of the subject matter to real life, their limited mathematical skills, ineffective teachers who moved too quickly through the content, and inappropriate teaching methods that focused on the memorisation of facts.
Research Question 3.1.2: What influences secondary students’ decisions to undertake post-secondary education in science?

Overview. Research Question 3.1.2 enquired about the factors that influenced secondary students’ decision-making processes to study science after completing high school. Students with high science self-concepts had strong intentions to study science, even after their secondary education. These students had high levels of academic and career aspirations in science. Some students expressed that they wanted to become strong researchers in the field of science. Each of these themes is discussed separately in the following subsections.

Students’ interest in the subject. Students’ interest in the continuation of elective science subjects is highly important, as illustrated by the following comments from students with high science self-concepts:

Yes I would like to do science in Year 11 and 12. Because I want to have a good future and it is like very interesting [St67, Year 8].

Science is pretty much an okay subject for me. In my opinion some subjects are more interesting than others. I plan to do physics and chemistry. Personally, I like physics the most [St49, Year 10].

I find chemistry and biology are more interesting. I am interested in the human body and the health aspects of biology. Chemistry is really interesting. I like how things around us are made [St5, Year 11].

Conversely, students with low self-concepts typically held opposite opinions about the subject and did not want to continue science after completing secondary school, as illustrated by the following comments:

No, I don’t want to continue it. I don’t find it’s useful. There are not many scientists around. I don’t like it [St21, Year 8].

I wouldn’t study it. I don’t like science. It’s kind of boring and not interesting [St58, Year 9].
I am not interested in science. No, I don’t want to continue studying it. I like English, maths, and sport. [St25, Year 10].

Science educational and career aspirations. Students who have high science self-concepts are very keen to pursue further studies in science and have a career in a science field. Moreover, they enjoy science and want to understand the subject well, in order to understand the world. These students reported wanting to continue studying science. The following quotes demonstrate students’ science educational aspirations:

I like new pracs and things like that. Things like using the Bunsen burner. I want to continue my studies in science to get a good job [St24, Year 8].

I really do want to continue science. Because I want to continue my studies based on science. I want to stick to learning more about all the things in this world and how they work [St64, Year 8].

I will probably go to the University of Sydney. I am pretty sure they would have some science courses. I really like science, it comes to me a bit naturally. Because I’ve never really touched studying hard. I get most of the things we do in the class. I just find it really interesting most of the time to see how different chemicals can react, how physics works [St2, Year 10].

Other students expressed their intention to pursue a career in science after completing their tertiary education. Many already had a particular career in mind, as demonstrated by the following statements:

I want to do forensic science, forensic biology in particular. …. I like forensic because I like exposure of people like we see in the news with like missing persons and stuff like a body has been found, like finding criminals. I want to research it, I feel like it is really interesting, so I want to do it [St43, Year 11].
I would definitely like to continue my science career onto a university. I would really like to have a career in physics. Because I just love it ... In my mind I want to become the next Einstein [St66, Year 8].

I am planning to going to a university to study medical science. I am especially interested in microbiology especially DNA anything within the body like DNA or your blood cells and all the little things I am very interested in ... I kind of prefer that over learning anything else [St40, Year 11].

In contrast, students with low science self-concepts were not as interested in science and typically were not willing to continue their studies in science. Most of them were interested in pursuing other subjects and wanted a career in a field other than science, as illustrated by the following quotes:

I don’t feel like doing any science when I grow up. Because it’s not how I am. It’s not what I need in my future. Because I wouldn’t choose science [St72, Year 7].

I wouldn’t study it. I don’t like science. It’s kind of boring. I want to do business [St58, Year 9].

I don’t really like, or get excited for science. I like other subjects. When I finish Year 12 I’ll be thinking of having my career in creative business and art designing [St62, Year 10].

I have thought of a career. But it doesn’t have anything to do with science [St11, Year 11].

Relevance of the subject to day-to-day life. The perception of relevance of subject matter creates meaningful learning for students. If students can relate to and use what they learn from school, they understand and realise the need for it. Students with high science self-concepts appreciate the relevance of science to real life situations. Hence, they want to continue studying science, as they feel it is more
important, and applicable in daily life. A number of quotes from students support this finding:

*I do enjoy learning. Like about the human body, like how it works and find the answer I like biology. I like working with the human body, knowing about diseases. Probably I would like medicine [St4, Year 10].*

*I am continuing doing medical science. Biology is more applied. That kind of applies with medical science as well and I enjoy learning about the body and knowing about myself and I think in the society like today when you are getting increases in cases of new diseases and cancers like it will really help. I am thinking of possibly going into research, maybe possibly cancer research [St40, Year 11].*

The students with low self-concepts in science also found the subject relevant to their life. For example, a student from Year 11 said that “*To understand the world around you science is important. It’s applicable to every day*” [St11, Year 11].

**Conclusion.** Students’ interest in science, career aspirations in science, and the perceived relevance of science to day-to-day life are some of the determinants of students’ decision-making in relation to continuing science education at post-secondary level. When students see the relation between science subjects and real life activities and experiences, they are more likely to pursue further science studies.

**Research Question 3.2.1: To what extent do science self-concepts relate to science aspirations?**

**Overview.** Research Question 3.2.1 sought to investigate the relations between students’ science self-concepts and their science aspirations. The results suggest that in general, students with high science self-concepts demonstrate high science educational and career aspirations that ultimately support and lead towards students’ higher achievement in science. The following expressions from students with high science self-concepts illustrate this finding.
I would definitely like to continue my science career on to a university. I would really like to have a career in physics. Well I try to stay best in my marks simply because of the fact that a lot of science involves around that and I try to get good marks in maths as it can help me towards my science career [St66, Year 8].

I do have a steady amount of interest in all the disciplines of science. I have a particular interest in biology and chemistry over the others and I do have an interest in physics. I want a medical degree [St30, Year 9].

... probably studying chemistry or biology at a university and I want to become a teacher because it makes me feel good like when you help out and pass down to the younger generation, it makes you feel good about yourself .... In biology I guess I am doing all right compared to my other subjects. I think my score is pretty decent. I think my score in chemistry is actually pretty good compared to my other subjects [St41, Year 11].

Conversely, students with low science self-concepts held low science educational and career aspirations. For example:

I don’t really like it, well it’s hard. No. I’ll go to do designing. Housing, something like arts subjects. The best subjects I am good in are dancing, PE, and visual arts [St63, Year 10].

**Conclusion.** The above findings suggest that students’ science self-concepts are related to their academic and career aspirations in science. Students with strong science self-concepts tended to want to pursue further studies in science, and had aspirations to careers in science. In contrast, students with low science self-concepts tended to achieve poorly in science and had little interest in pursuing it in future educational or occupational pursuits.
Research Question 3.2.2: To what extent do science self-concepts relate to science achievement?

Overview. Research Question 3.2.2 explored the relations between students’ science self-concepts and their science achievement. The achievement levels of students with high science self-concepts were generally greater than those of students with low science self-concepts. The following quotes from students with high science self-concepts support this argument.

*I think science is one of my best subjects in school. I understand a lot more and I enjoy doing it. I am doing very well in science, better than other subjects [St16, Year 8].*

*In science I have always been at the top of the class. Whereas with other subjects I have got average scores except for maths. For maths, I got higher scores, now maths is going down and everything is just average. But science is something I love [St1, Year 10].*

*In biology I guess I am doing all right. I think my score in chemistry is actually pretty good compared to my other subjects [St41, Year 11].*

Not surprisingly, the science performance of students with low self-concepts was poor. This could be due to a number of reasons, such as their poor attitudes towards science, their lack of enjoyment of the subject, the lesser time they spent studying it, and the difficulty of the subject. Some direct quotes from students with low science self-concepts are as follows.

*I don’t really do good at science. With other subjects I do better [St20, Year 8].*

*My marks in science are by far the lowest I get in any tests except for a few occasions. My results in science on average are 20% lower than my marks in English and this led me not to enjoy science as much as I probably could if I got higher grades. [St34, Year 9].*
I do a lot better in other subjects: Arts, English than science [St52, Year12].

**Conclusion.** Students’ science achievement is related to their science self-concepts. Achievement in science is greater for students with high science self-concepts than for students with low science self-concepts. Furthermore, students with high science self-concepts report that they do better in science than in their other subjects.

**Research Question 3.2.3: To what extent does motivation relate to science aspirations?**

**Overview.** Research Question 3.2.3 sought to investigate the relations between students’ science motivation and their science aspirations. The results reveal that the students with high motivation demonstrated high science educational and career aspirations. The students’ opinions on the above are illustrated by the following comments.

*I think science is one of my best subjects in school. I understand a lot more and I enjoy doing it. I may be doing something in science [St16, Year 8].*

*My experience in science has been pretty good. My interest in science started when I was 10. I have an ambition to work in the medical field [St30, Year 9].*

*Studying science is something I really enjoy. Because it's not only fun like you know things around you. I am continuing doing medical science [St5, Year 11].*

Conversely, the students with low motivation demonstrated less intention to pursue studies in science and find a career in science. Following are some of the responses given by students with low motivation.

*Science is too challenging and too much to learn. I would like to go to a university to do arts and media [St28, Year 7].*

*I don’t want to do science after Year 10. Because I find it’s hard and I don’t like it [St33, Year 9].*
I am really bad in science. All that chemistry and physics stuff I never enjoyed. I’d like to do psychology [St54, Year 11].

Students’ better performance, enjoyment, and understanding of the subject were some of the drivers in motivating students to study science. The above comments from students show that students’ science motivation affects their intentions to study science further and pursue a career in this area.

**Conclusion.** Students with high science motivation demonstrate higher science educational and career aspirations than students who are less motivated. Hence, students’ motivation is related to their science aspirations.

**Research Question 3.2.4: To what extent does motivation relate to science achievement?**

**Overview.** Research Question 3.2.4 explores the relations between students’ motivation and achievement in science. The results show that students with high motivation demonstrate better achievement in science. The students’ opinions on the above are illustrated by the following comments:

*Science is lot more passionate. I just enjoy science more than any other subject. My science is always consistent and maths has started going down. Just understanding new things. Always something new to learn in science. Chemistry and physics I understand easily [St1, Year 10].*

*I’ll do more science in high school. Chemistry and biology. Because my mum helps me a lot in science. She is a teacher. She teaches chemistry. I am doing very well in science better than other subjects [St16, Year 8].*

Of the above two quotes, the first student (St1) is motivated through understanding and enjoying the subject. The second student (St16) is motivated because her mother helps her with the subject. Both are performing well in their science subject.

Students who displayed less motivation to do science did not achieve well in science. Following is a response given by a low science self-concept student.
I find studying science my results aren’t very good. Subject is quite hard to study. Some of the topics are quite confusing. My marks in science are by far the lowest I get in any tests. I would say that science is not one of the best subjects to do in school. Because it’s quite difficult [St34, Year 9].

I’m not interested in science. I am terrible in science but average in all other subjects. I like English, maths, and sports [St35, Year 10].

According to the above two quotes, both students are not doing well in science. The first student (St34) was not motivated, due to the perceived difficulty of the subject. The second student (St35) was not motivated because of a lack of interest in the subject. As a result, their achievement in science compared to other subjects is low.

**Conclusion.** Students who are highly motivated to do science perform better than students who are less motivated. Hence, students’ motivation seems closely related to their achievement in the different science disciplines.

**Research Question 3.3.1:** Are there other issues that influence students’ decision-making process on whether or not to pursue a further science education option?

**Overview.** Research Question 3.3.1 sought to explore any additional issues that arose from the qualitative data that did not correspond to an initial research question. In addition to students’ science self-concepts, motivation, and aspirations, some other external factors that influenced students’ decisions on whether or not they continued with further education in the field of science, included: the Australian Tertiary Admission Rank (ATAR), the availability of career opportunities, and student assessment procedures.

**ATAR.** ATAR\(^2\) is the primary criterion for entry into most undergraduate-entry university programs in Australia. It was introduced gradually between 2009 and 2010 to replace the Universities Admission Index, the Equivalent National Tertiary Entrance Rank, and the Tertiary Entrance Rank. ATAR is a percentile awarded to students upon completion of Year 12, and is used to determine offers made for places in undergraduate-entry university programs. During the interviews, some students stated the opinion that if they elected “easy” subjects they could
achieve a better ATAR than if they chose difficult subjects. Since some students thought that science was more difficult than many other subjects, they tended to choose easy subjects by omitting science in their senior years of secondary schooling (Years 11 & 12), as illustrated by the following statement:

Everyone is doing 4 units maths or another higher ranking subject. A person doing 4 unit maths, to get ATAR 99, has to achieve in the top 56% of the state. If you want to do biology you have to be in the top 20% to get an ATAR of 99. Me in particular, I would rather focus on easier subjects rather than do double maths for my ATAR which could bring it down. Chemistry and physics both you have to finish in top 11% to get ATAR 99 or higher. ATAR influences selecting subjects in HSC. Because people see that it’s a hard subject to do and pick up pretty easy subjects instead [St46, Year 9].

There is high competition among the students to obtain a high ATAR. The above quote implies that students tend to choose subjects that they believe will help them more easily obtain a high ATAR. If students choose subjects like chemistry and physics, they have to be in the top 11% in the state in order to obtain an ATAR of 99. As chemistry and physics are comparably harder than many other HSC subjects, usually they are chosen by smarter students.

However, this student believes that if they choose four-unit mathematics, they only have to be in the top 56%, while for biology this requires getting in the top 20% in order to obtain the same ATAR of 99. Consequently, students tend to select more advantageous subjects at the HSC level in order to obtain a better ATAR. As the ATAR has an enormous influence on their ability to gain admission to tertiary education and to select their preferred university and course, they are reluctant to choose science subjects, which are renowned for their difficulty. This situation seems to lead students to select non-science subjects rather than science subjects for the HSC.

Science Assessments. Student assessment procedures also affected students’ like or dislike of particular school subjects. The assessment procedures in some subjects are considered easier for some students than others. Hence, students tended to choose subjects in which they performed better on the assessment tasks. Students believed that science assessments required more than merely recalling or reproducing content, and required new applications which, in their opinion, made science assessments more difficult, in comparison to their other subjects. Accordingly, some students may choose subjects other than science, as science assessments are often perceived to be difficult, as is illustrated by the following comments from students with high science self-concepts.

*The questions in science aren’t straightforward. You have to think about them [St8, Year 11].*

*In a lot of subjects we have to remember, so they are content based. But in science you need to be able to apply what you learn which is not something you are doing in a lot of other subjects, which makes it harder [St5, Year 11].*

The following quote from a student with a low science self-concept illustrates a similar opinion to that expressed in the previous quote that science assessment procedures are more difficult compared to those in other subjects, due to the need to apply their knowledge.

*In class for me and my friends science is interesting. When it comes to assessments and stuff the questions sometimes seemed a bit irrelevant to what we are doing in the class. Assessments in science can be a bit tricky. Usually when I study for exams, I memorise from my work. It’s really in the knowledge based part of the test. When I do the exams most of the work is applications [St14, Year 11].*

The availability of career opportunities in some disciplines of science was also associated with students’ decision-making processes in pursuing science. According to the following quotes from students with high science self-concepts, they did not believe that there were sufficient career opportunities in the field of
earth and environmental science, because “in earth and environmental science there is not much to find out” [St1, Year 10]. Thus, students might tend to drop this subject. The following quote indicates that it is also perceived to be hard to find a career in an earth and environmental science discipline.

If we think about future careers of science, earth and environmental stuff, most of them have already been looked at and done by scientists. Trying to get careers ... would be hard. Also it's kind of boring, rocks and stuff. In chemistry we have reactions happening, we have different stuff [St2, Year 10].

The following quotes are from students who had low science self-concepts but still recognised the link between science and future career options.

Science is something that helps me to find many possible careers in the future. I think it's a good subject [St14, Year 11].

I chose science because I feel like a medical career [St13, Year 11].

**Conclusion.** The ATAR, science assessment procedures, and the availability of career opportunities in science, in addition to matters addressed in the various research questions, influenced students’ decision-making in regard to studying science. Students preferred assessment procedures that did not involve new applications and questioned what career opportunities were available in science.
Findings from the Teacher Interviews

Research Question 3.4.1: What do teachers believe influences secondary students’ decisions to undertake science subjects at school?

Overview. Research Question 3.4.1 asked what teachers believe were the factors that influenced students’ decisions to study science subjects at the secondary school level. According to teachers, several aspects related to students’ decision-making process in relation to choosing science subjects. For convenience, these factors are organised around the following broad themes: parent and teacher factors, student characteristics, and characteristics of the science subjects. The parent and teacher factors include parental influence, teacher influence, and teaching methods. Student characteristics include students’ interest, enjoyment, enthusiasm, career aspirations, and academic performance in science. The difficulty of the subject, the perceived relevance of the subject matter to day-to-day life, and the amount of subject matter content involved, were identified as subject characteristics. The above broad themes are discussed below; explanations follow the quotes from these teachers.

Parent and teacher factors. According to the teachers, it seems that parents and teachers play significant roles as mediators in steering students towards the discipline of science. The following quotes are illustrative of teachers’ opinions that parents significantly influence their children’s decision to pursue science:

Another way is parental push. Our school has a lot of kids from non-English speaking backgrounds. Particularly Asian background people often put pressure on kids to choose science [T1].

Parents will be driving their kids into science [T2].

Some of them are encouraged by their parents and teachers [T9].

As the last quote above shows, teachers also influence students in their decision to pursue science. Other quotes demonstrating the influence of teachers are as follows:
If kids like their teacher, students learn a lot from the teacher, students choose it [T1].

We have to get teachers who are able to make teaching exciting, make learning exciting, make learning purposeful, and make them understand [T6].

On my staff I’ve got couple of teachers who go out of their way and make science exciting and they get a high proportion of students going on to do science in Year 11 and 12 [T5].

Teaching science entails teaching many scientific concepts. This process is called ‘conceptualization’, and it is not an easy task. Teachers have to use very effective teaching methods in order to facilitate meaningful learning. These views are consistent with the following quotes:

We want to make science interesting. … teachers really want the best from the students, at the same time it’s difficult to organize everything at an interesting level with too much work [T1].

It’s challenging for teachers, as we lack technology. We lack time, and have few resources and funding. [To make it] relevant to the everyday life they do need writing, they need to see videos, they do need to see experiments, they do need to see what something means because we have new technology. We have selective kids. Our programmes should be benefiting everyone rather than giving and creating a worksheet or a fun activity in the class that doesn’t really interest them with the technology that we’ve got. So I went to UWS. So we were taught on an outcome basis. How to make HSC questions and do a marking criteria, that’s very important [T4].

You get students who love science, you get students who don’t like science depending on the teacher’s style … this has the biggest impact on how they feel about the subject, the more fun the teacher is in delivering the content … and skills and so on, it is more likely they are going to enjoy science. It depends on the year level how teachers are going with the content [T11].
**Student characteristics.** The following quotes illustrate those factors teachers believe will influence students’ decisions to pursue science at school level. The identified themes are presented separately to other evidence from the teachers’ interviews. Not surprisingly, interest, enjoyment, and enthusiasm were found to be significant factors that influenced students’ engagement in science.

*Number one is interest [T9].*

*In the senior years, probably comes down to interest [T2].*

*They choose it if they like it and enjoy it [T5].*

According to the following quotes, students start Year 7 science with a lot of enthusiasm. However, their enthusiasm gradually declines in the following years, due to many inter-related factors, such as the difficulty of the subject, less enjoyment of the subject, and having to deal with more content. Teachers suggested that educators have to do something in order to retain and enhance the students’ interest in and enthusiasm for science.

*Most kids that come to Year 7 love the Bunsen burner but at the end of the year they switch off, quite difficult with the content they get through, they love experiments, they love prac, usually students are more confident in prac work than theory [T3].*

*They do enjoy science especially in Year 7, as they come to Year 10 many switch off science; instead they choose a subject that is easy for them [T11].*

*Especially juniors enjoy science, when years pass on and the curriculum becomes dry … less practical based … more theory based, in Year 10 there are not many experiments [T11].*

*When they come here in Year 7 they are very excited and fantastic, and simply most kids in Year 7 are very enthusiastic and enjoy science. Over*
the years it seems to decline, the enthusiasm. But if we do have creative teachers who keep them inspired that enthusiasm doesn’t last. They find Year 11 too hard. Some kids are finding HSC subjects too hard as well. It’s more conceptual. We can’t just feed them information. Actually we have to conceptualize things. This is hard for kids. Media does have some influence. Payments for scientists are not good in Australia [T5].

I think up until Year 8 most of them consider science pretty exciting and fun, up until Year 8 things are going to be fun, hands on prac and they don’t think it’s hard, by the time they get to Year 10 they just want to hear how science relates to them personally, how it is of interest to them, how it relates to their life, a lot of them by the time they get to Year 10 tend to think it’s too hard, so something happens between Year 8 and 9 I reckon. We lose a lot of kids [T7].

When students have strong educational and career aspirations in science they tend to pursue science at the HSC level. The following quotes from teachers show evidence for this. As stated by one teacher: “Who want to do engineering, do physics and chemistry” [T5].

The following remarks from teachers indicated that there are not enough career opportunities in Australia for science graduates. This may affect students’ decision-making process in relation to continuing their education in the field of science.

Probably not a good career path. Career path is limited and not financially rewarding [T3].

We are not striking a balance in terms of supply and demand, not enough jobs for science graduates in Australia [T5].

Students’ academic performance also affects the studying of science at school level. For example:
There are number of ways it is informed. One is academic performance. That has an effect if it’s good. How they have gone with science in the past in junior years particularly affects what they will choose most often in senior years [T1].

If the kids are really good at science then they do science in Year 11 and 12, maybe looking for career prospects [T3].

Characteristics of science as a subject. The science syllabus also influences students’ decision-making process. Teachers had the opinion that the perceived difficulty of the science subject compared to other subjects, the amount of subject matter, and the relevance of subject matter to day-to-day life also affected decision-making in regard to choosing to pursue science. The opinions expressed by the teachers reinforce the findings derived from the student groups, demonstrating consistency from multiple stakeholders in the qualitative investigation. For example, one of the teachers said that “Kids in the junior school drop it because they do find it difficult” [T5]. The teachers’ perspectives given below show that students experience some difficulty in understanding the subject matter in science, compared to other subjects.

Generally speaking most of them find that science is one of the hardest subjects. I think it’s so intense, the actual curriculum and how much you get through and the concepts behind everything that we teach. So many concepts and it’s not a subject that can always be so fun. Test regulations minimise the practicals that we can do in certain things. With the intensity and the restrictions kids find it very ... very hard. [T4].

They find science is more difficult than PDHPE and arts. Science requires thinking [T6].

Science is hard. Students say “Miss, science is hard, we like you, but we don’t like science”. Concepts are hard to understand. Maybe the way these are taught [T9].
The amount of content to be studied also seemed to be very important in students’ selection of science for their studies. Teachers acknowledged a problem of excessive content in the science discipline. This has potential to impact on the quality of lessons taught and on the learning experiences for the students. Practical rather than theoretical lessons were suggested to be more appropriate for teaching science. These findings are supported by the following quotes.

*Hardest thing is the content to get through. I think students like less content and more prac. The curriculum needs to be changed with more focus on prac work.* [T3].

*The workload for teachers is a lot, a lot of content to be covered. We need help. Schools should be checked regularly. It’s very hard to draw a line in the sand, being a teacher. Very different learning, very different speeds. In terms of planning I spend a lot of time at home* [T8].

Teachers believed that science should be made more relevant to students’ real world experience, with more practical work. More practical sessions are important and necessary in order to develop and enhance students’ skills and experience with real life scientific investigations.

*They think it’s irrelevant, a lot of students think science doesn’t matter... which is upsetting, they don’t understand the mindset, they don’t understand we are in a society due to its discoveries, even laws things like that. They don’t understand why we have to keep learning about it, if it’s already been discovered, why we have to revisit it and this makes it a bit disappointing* [T8].

*We have to emphasize as often as possible and relate to our day-to-day life, then they can see the significance. It needs to be relevant, we definitely need to promote the relevancy of science in schools, so we can be a leading country in the world in terms of innovations and new inventions etc. in various fields of medicine, chemistry, physics leading the world* [T6].
I think we need to still make it better to really link it to what is happening in the very exciting science world, we’re living in new technology, and breakthroughs in biology, physics, and in material science are just mind blowing. Conceptually science is hard, I don’t know that we do that very well. We try to make more interesting and tend to do a lot of practicals, more like demonstrations, children have to do actual science investigations. If we use small pieces of magnesium what difference will it make if we use lumpy magnesium? What difference that would make if we use warmer acid, what you can see that makes: so making every prac like an actual scientific investigation, I think that’s what we need to do more, in practical terms it's always challenging for the teachers [T7].

**Conclusion.** According to teachers, the factors influencing students’ decisions to choose science included: parent and teacher influences, teaching methods, students’ interest and enthusiasm, career aspirations, students’ performance, the difficulty of the science subject, the amount of subject matter content, and the relevance of science to real life.

**Research Question 3.4.2: What do teachers believe influences secondary students’ decisions to undertake post-secondary education in science?**

**Overview.** Research Question 3.4.2 investigated teachers’ beliefs about students’ decisions to undertake tertiary education in science. Based on the views of the teachers interviewed, several factors can conspire simultaneously to influence a student’s desire to pursue science at the post-secondary level. Clear and discrete themes did not readily emerge, and no attempt was made to group the findings according to general themes for this research question.

In general, the results demonstrated that teachers believed that if students felt that they were successful in a particular subject they would probably want to follow and continue their education in a discipline closely related to that subject. However, their ambitions and interest also affect this process. Students with inspiring teachers were more likely to enjoy those subjects and more likely to imitate their teachers; this would eventually help them to continue with the related subject discipline in their future education. This is illustrated by the following quote.
Some teachers are quite good. Some students choose certain subjects based on the science teachers that are attached to that subject [T2].

Teachers also reported that family influence, students’ career aspirations, financial rewards, and peer pressure also impacted on a student's decision to choose science for their post-secondary education. Given that science courses are more expensive and more difficult than other courses, some students may be reluctant to pursue a science career if they do not feel they will be rewarded appropriately. In addition, teachers felt that parents want to direct their children towards a career according to their own expectations. The following perspectives from three teachers support these views:

Family influence, what their mother and father like in career and their ambitions. Many children consider value for money. Science courses are a bit more expensive and they want to know that they are going to have a career that is going to pay them well [T7].

What influences them are career ambitions. What they want to do in the future. If they want to be a doctor they take science, if they want to do pharmaceuticals related work, if they want to do engineering they do science. Sometimes parents have an influence. What we had last year, yes Year 12 last year, her mother is a doctor, she also wanted to be a doctor, something like that. Sometimes they are influenced by teachers. If they are getting good marks in science ... their achievement. Even if they are interested in science they want to understand [T9].

Students tended to think that they would be better supported and less isolated in the future if they chose the same discipline as their friends in post-secondary education. Thus, friends tended to select similar subjects in secondary school. For example, a teacher said that “Peer pressure, friends’ pressure, may influence what friends are doing” [T11]. However, it seems that peer pressure does not have much influence in selecting students’ subjects at the post-secondary level.
Conclusion. Students’ academic life experience, career aspirations, interest, family influence, career ambitions, financial rewards, and peer pressure, in addition to teacher characteristics, affect students’ decision-making processes in pursuing science at the post-secondary level.

Research Question 3.4.3: What other issues, beyond the immediate school context identified by teachers, influence students’ decision-making process regarding whether or not to pursue further science education?

Overview. There are other factors related to promoting school science education that may ultimately or indirectly affect students’ decision-making process in regard to studying science. These include: a lack of adequate teacher training programmes, teacher reward issues, insufficient promotion of science outside schools, and inadequate influence from the media. These themes are discussed separately with supporting quotes from teachers as follows.

Teacher training courses. The interview data revealed that teachers demand more refresher training courses in the new technology, in order to make them more efficient, resourceful, and competent. They expect strong support from the NSW Department of Education and Communities in this regard. They also demand better infrastructure and other facilities related to practical work, with the intention of conducting more practical work to arouse the students’ curiosity and develop their enthusiasm for the subject. The following quotes from teachers support this finding.

Better to train science people, hope the government learns not to import people from overseas in the cheap way; it’s not the answer, need to train the people in the right line [T1].

Professional associations like NSW Lions Teachers’ Association, is very strong. Lions in Sydney are both strong and do a lot of work, they’ve run conferences so we’ve got very good professional development, NSW Science Teachers Association. Like New South Wales Sydney Science Teachers association, every month they’ve got a workshop for beginning teachers or science demonstrations, very good, I don’t believe there’s much support from the Department, a lot of outside bodies doing a lot of
competitions and universities are running a lot of stuff for kids. Universities are the major organizations to run competitions, make multimedia things, so much happening. It’s good [T5].

The Department has to do more, we aren’t getting proper guidelines, this is the depth, this is the length and this is the breadth that we need to go, some of us are going too deep, some others are skimming the surface. We are going again for a national state, national level, we need people coming to assist teachers, releasing teachers during the term let’s have workshops, more exposure, more hands on experience to become more qualified ... more experienced ... more confident teachers, national curriculum is important, we need to have a lot of workshops ahead and show the teachers are confident and able to stand and deliver [T6].

Financial and social rewards. Teachers also believed that they should be rewarded both financially and socially in order to uplift science education in schools. This view is illustrated by the following quote:

Certainly send the teachers in the right direction, providing incentives and financial need, keeping the teachers, good teachers can make science exciting they need to be rewarded financially and in other ways. More ever than before teachers are working hard, it’s not fair, more younger people are coming at the moment and I think some quality people are good, frustrated at the fact that some days good people are coming as casual, we can’t have them, they have to be forced to go elsewhere, it’s a shame, they come to the school, love the kids, principal doesn’t want them to stay, there are four year trained professionals, they should be treated in that way to ensure that they do their job. If the teacher is going unprepared, doesn’t do the work, kids get upset, it’s a hard job [T1].

Promoting science both in school and externally. Teachers believed that science is not promoted enough in schools, and externally. One of the teachers said that “A lot of things need to be done to encourage science in school and outside” [T5]. This is supported by a quote from another teacher, as follows.
Science is not promoted enough in schools and homes. It’s very difficult to teach some of the harder concepts when we have a very uneasy class, there should be a lot of time dedicated to each concept [T8].

**Lack of sufficient influence from the media.** Teachers believe that the media should engage more actively and efficiently in promoting science. The media could do a lot of things in order to make science more popular and hands-on with young science students, to encourage students to choose science for their future studies. The following quotes from teachers illustrate this theme.

*What goes on in the media influences* [Popular attitudes about important science-related topics] ... *nuclear bombs* ... *disease transfer or biologically controlled things* [T1].

*A lot of reality TV shows* ... *good for science, big bang theory* ... *more interactions, one TV show can cause kids to know more about science. It’s a good thing. TV, media, Internet are the major ones that kids are more interested in these days* [T10].

**Conclusion.** The lack of adequate teacher training, an insufficient reward system based on teachers’ experience and performance, the lack of promotion of science outside of the schools, and inadequate support from the media are some of the other issues identified by teachers, that impact on the uptake of science in schools. Though many factors and themes were identified, there was considerable overlap in the findings between teacher interviews and student focus groups.

The graph in Figure 8.1 shows the percentage responses for barriers perceived by teachers in relation to school science education. It demonstrates that all teachers accept that science is a difficult subject. Of the teacher sample, 7 out of 11 teachers believed that students see science learning as not enjoyable. Nearly half of the teachers thought that there weren’t sufficient career opportunities in the field of science in Australia. Three (3) out of 11 teachers expressed the view that they do not have enough teacher training, and that learning science is not financially rewarding for students.
Figure 8.1 Barriers to school science education perceived by teachers

Chapter Summary

The themes identified as factors affecting secondary school students’ willingness to undertake science subjects were mainly associated with: subject characteristics, teacher characteristics, prior performance, students’ interests, family expectations, and career aspirations. Subject characteristics found to positively influence students’ decision to enrol in science subjects at school included: the extent to which students enjoyed science, having a practical or experiment-based delivery of science lessons, the perceived relevance of science to day-to-day life, and the extent to which the content of science was perceived to be easy. In contrast, high content and difficulty levels within the subject, deterred students from undertaking science subjects. In addition, inspiring and passionate teaching made the subject more interesting to the students. Generally, students who performed well in science were more interested and engaged with the subject. The students who had a specific interest in science enjoyed the subject more and were more motivated to continue. Some students reported that they were influenced by their family’s attitudes towards science, and by the financial rewards of pursuing future careers within the discipline. Students with high and with low science self-concepts both identified the above factors as important, while clearly viewing them differently. Students’ science self-concepts and motivation were related to their science aspirations and achievement.

According to teachers, the factors influencing students to engage with science and perform well at secondary level are: students’ performance, parents’
expectations, teacher characteristics, students’ interests, career aspirations, the difficulty of the subject, and the relevance of the subject to day-to-day life. Further, students’ experience in their academic life, career aspirations, interest, and peer pressure affect the decision-making process in relation to pursuing science at post-secondary level.

The barriers to promoting science in schools identified by science teachers were the difficulty of science subjects, inadequate teaching methods, the lack of sufficient career opportunities in science, the high content level science curricula, the lack of adequate teacher training, of a teacher reward system, and inadequate support from the mass media. In addition, the decline of students’ enthusiasm from Year 7 to the senior school years, the perceived lack of relevance of the subject matter to real life situations, and a lack of support from within the home environment, were some other issues involved in encouraging students to turn away from the field of science.

The results from Study 3 have enriched and strengthened the findings of the quantitative study, providing further insight into why students engage in science, and why they do not. Moreover, key issues and findings, emerged from this study that were not found in the quantitative studies. The implications of these qualitative findings for theory, research, and practice are discussed in the following chapter.
CHAPTER 9

DISCUSSION AND IMPLICATIONS FOR THEORY, RESEARCH, AND PRACTICE

“If data are allowed to speak for themselves, they will typically lie to you” (Schmidt, 2010, p. 233).

Introduction

To facilitate interpretation of data, this chapter brings together findings from the three studies, with interpretations given in the context of theory, research, and practice. Thus, the discussion is presented in three separate sections, which correspond to the three studies in this investigation. In each section, the results of the study are discussed and the strengths and limitations are investigated and evaluated, followed by implications for theory, research, and practice. As research and theory are inextricably linked (Marsh & Hattie, 1996), reference is made where appropriate to previous chapters. This chapter concludes by introducing a general set of recommendations for research and practice.

Study 1: Psychometric Properties of the Instrumentation

Overview

The psychometric properties of the newly developed SSQ are discussed in this section, based on the results presented for Study 1 (see Chapter 6). The SSQ consists of the SSDQ, SMQ, and SAQ. While the focus of this research was on exploring relations between latent constructs, Marsh, Ellis, Parada, Richards, and Heubeck (2005) suggest that the internal structure of constructs should be investigated before considering the relations between constructs. The internal structure is referred to by Cronbach and Meehl (1955) as the ‘within network’ and is the focus of Study 1, while the relations between constructs are referred to as the ‘between network’, and are the focus of Study 2. Together, these networks make up the 'nomological network'.
network’ (p. 290). The internal structure of the instrument’s scales was assessed on the basis of reliability, structural validity, and invariance for the given sample.

Reliability
Measurement scales that are constructed and used without attention to reliability may produce scores with no clear psychological meaning, and may contribute to inaccurate psychological conclusions (Furr, 2011). Hence, assessing reliability is very important in assessing the psychometric properties of a survey instrument, as it has implications for the entire research process. While the limitations of Cronbach’s alphas are noted and discussed in Chapter 5, it is customary to report them, so they are reported in this investigation.

There is no clear cut-off separating good and poor reliability, but values of .70 or .80 are generally viewed as sufficient for research (Furr, 2011), while values of at least .60 are considered acceptable (Aron & Aron, 2003). Cronbach’s alpha values were reported for all subscales of the SSQ for the total sample, and for the specific subgroups of interest.

Reliability of the SSDQ. The alpha values for all subscales of the SSDQ were well above the recommended desirable value of .70 for the total sample. Further, alpha values were above .70 for all subgroups, except for stage of secondary schooling (i.e., Stage 4, Stage 5, and Stage 6), which had a value above .60, which is still considered acceptable (Aron & Aron, 2003). These results suggest that the subscales of the SSDQ are reliable measures of the constructs they were designed to assess for the total sample, and across the groupings of gender and different stages of secondary schooling. Hence, under the assumptions of classical test theory, variance among observed scores is more likely to reflect true differences in the scores, rather than to be the result of measurement error (see Allen & Yen, 2002; Crocker & Algina, 2008).

Reliability of the SMQ. All Cronbach’s alpha values for the SMQ subscales were well above the recommended desirable value of .70 for the total sample and the subgroups of interest (i.e., gender and stages of secondary schooling). Hence, all the subscales in the SMQ for general science used in this research are reliable measures for the total sample, and for the groupings of gender and different stages of secondary schooling.
Reliability of the SAQ. As mentioned in Chapters 4 and 5 there are two types of science aspirations considered in this study namely science educational aspirations and science career aspirations. Similarly to the SMQ, all Cronbach’s alpha values for the subscales (i.e., Science Educational Aspirations and Career Aspirations) were well above .70 for the total sample and for the subgroups of interest (i.e., gender and stages of secondary schooling). Hence, all the subscales of the SAQ demonstrate high reliability for the total sample and for the groupings of gender and secondary schooling stage.

Structural Validity

The structural validity of each scale of the SSQ was assessed according to the CFA model results (i.e., RMSEA, CFI, and TLI values), item-to-factor loadings, and the factor correlations. The structural validity of the overall instrument was assessed using the same parameters as above when all the scales were combined together in CFA analysis; the results are shown in Chapter 6.

SSDQ. The CFA model fit statistics show that the hypothesised factor structure of the SSDQ is well represented by the data. Factor loadings of all the items were sufficiently high (i.e., greater than .50, Hair et al., 2006), thus demonstrating that the items were good measures of their respective factors. The factor correlations ranged from .48 to .76. According to Cohen’s conventions (Cumming, 2012) for effect sizes, these correlations are within the ranges of medium and large respectively. The absence of very high factor correlations suggests the distinctness of the factors. That is, each factor measures a distinct construct.

The lowest correlation (i.e., .48) appears between Biology and Physics Self-concepts. While low in comparison to the other correlations among factors of the SSDQ, this correlation of .48 is substantive in magnitude, as would be expected, given that biology and physics are both disciplines of science. A likely reason for the lower correlation, compared with other correlations for the SSDQ factors, is the very distinct difference in the subject matter of the two disciplines. As biology relates to the human body and life more generally, its subject matter is more readily understood and appreciated. For example, students readily recognise the many applications of biology in the areas of human health, food, sports etc. However, physics typically deals with more abstract concepts pertaining to the behaviour of matter and energy. Further, while biology uses basic mathematical techniques (e.g.,
rates, percentages), physics uses advanced techniques (e.g., calculus). Hence, these differences are likely reflected in students’ self-concepts in biology and physics, as evidenced by their having a moderately low correlation of .48.

The correlations between Physics Self-concept and other science self-concepts were generally lower (i.e., .53 or less) than the other inter factor correlations, with the exception of Physics Self-concepts with Chemistry Self-concepts, which had a correlation of .60. Although physics and chemistry are distinct and while each has content that is unique to itself, there is considerable overlap. The basic concepts and principles in chemistry are related to the structural and chemical properties of matter and energy, while the basic concepts and principles in physics are related to the physical and behavioural properties of matter and energy. Given this overlap, the two disciplines are closely related; hence, students may perceive chemistry and physics as similar branches of science.

**SMQ.** The results of the CFA tests for SMQ revealed that students’ science motivation was not domain specific. That is, statistical analyses showed that students were not able to differentiate the different orientations in science motivation with respect to the different disciplines of science. Hence, the SMQ was examined only for general science.

A CFA yielded excellent fit statistics. Factor loadings of all the items were sufficiently high (i.e., greater than .50, Hair et al., 2006), demonstrating that the items were good measures of their respective factors. The factor correlations were moderate (ranging from .35 to .64), indicating the distinctness of the latent variables they were intended to measure.

**SAQ.** Similarly to the SMQ, the results of the CFA tests for SAQ revealed that it is not domain specific; hence, both factors (Science Educational Aspirations and Career Aspirations) were examined only for general science. For the hypothesised two-factor model, a CFA produced good fit statistics, while all factor loadings were high, thus demonstrating that all items were good indicators of their respective factors. While the two factors were highly correlated ($r = .94$), such a high correlation does not present any problems for statistical analyses, given that the two factors are outcome variables. This high correlation is to be expected, given that both factors are conceptually closely related, as indicated by the survey items. For example, an item in the Science Educational Aspirations subscale is “I hope I continue my Science studies”, while an item in the Science Career Aspirations
subscale is “I wish to get a good job in Science”. Given the high correlation, a one-factor model was tested and compared with the original two-factor model. The model fit statistics showed that the data were better represented by the two-factor model. These results provide good support for the structural validity of the SAQ.

**Invariance**

Within a sample it is typical for sub groups to exist, such as different age groups. It is also typical for these groups to differ on one or more measures of a survey instrument. While different scores are typical, and indeed are often expected, a necessary condition for the psychometric soundness of the instrument is that the scales and their items have the same meaning across the different groups (i.e., they demonstrate invariance). Invariance of the survey instrument was assessed by testing the different subgroups within the sample. Invariance was assessed using the criteria suggested by Cheung and Rensvold (2002) namely that changes in the CFI between the different models (with increasing restrictiveness) be less than .01. According to this criterion, the desirable minimal level of invariance was achieved for all scales of the SSQ across gender and stage of secondary schooling.

**Psychometric Properties of the SSQ**

The SSQ instrument comprises three scales: SSDQ, SMQ, and SAQ. Each of these scales was shown to possess sound psychometric properties. However, it is important to determine whether psychometric soundness is maintained when the three scales are combined. The psychometric properties of this instrument battery when all scales were combined together were tested; the results are given in Chapter 6. The CFA fit statistics provided good evidence that the structural validity of each scale of the SSQ was maintained. Specifically, all items loaded only on to those factors they were intended to load on. There were no correlated errors for items, and factors remained relatively distinct.

**Strengths and Limitations of Study 1**

The scales of the SSQ possess sound psychometric properties, in terms of reliability and structural validity. While this is a desirable outcome, Netemeyer et al. (2003) suggest that establishing structural validity is a necessary but insufficient condition for determining the construct validity of a measuring instrument. Specifically, good
fit statistics for the CFA indicate that the scale is measuring something. However, determining the nature of that something is a complex problem (Spector, 1992) (This is elaborated on in the Limitations section.) It is therefore important to be aware of what claims can be made in regard to the validity of the SSQ. As establishing validity is an ongoing process, this is not so much a weakness of the study; rather, it is a good indicator that the instrument possesses construct validity. Further, many of the items used in the SSQ were from existing instruments that have been shown to be psychometrically sound. Other items were modified in response to the present context (i.e., science students). In addition, further support for construct validity is gained from Study 3, where the participants expressed their opinions and views openly. Specifically, using the data from Study 1, the views of students with high science self-concepts were compared with students with low science self-concepts. This process is referred to by Spector (1992) as “known-groups validity” (p. 49).

The results of Study 1 provide an adequate foundation for proceeding with Study 2, as the instrument battery has been demonstrated to be psychometrically robust for the sample under consideration. As Study 2 examines relations between factors, it is possible to accumulate more evidence of the instrument’s construct validity by exploring the ‘between network’ relations (see Cronbach & Meehl, 1955).

There is no evidence to suggest that the construct validity of the SSQ was in any way compromised. However, given that the SSQ is a newly developed instrument, care needs to be taken when interpreting findings. To further investigate the psychometric properties of a survey instrument it is necessary to administer the instrument and test the results many times, over a considerable period of time (Noar, 2003), as establishing construct validity is a cumulative and ongoing process (Allen & Yen, 2002). A limitation of this investigation is that only one wave of data was used.

A further problem, often overlooked in the design and validation of survey scales, is determining whether or not the names assigned to factors are indeed correct (Kline, 2011). Although the proposed factor structure may fit with the data (an indication of structural validity), this does not necessarily mean that the labels assigned by the researcher are always correct. Although face validity is often desirable, there is no guarantee that a scale’s factors have been correctly identified. Essentially, CFA tests tell us the degree to which factors measure some construct, but they cannot by themselves, identify what the construct is. For example, it is possible
that the factor of Career Aspirations, which is intended to measure what students themselves aspire to with regard to a science career, may actually be a measure of what students believe their parents want for them in terms of a science career. As a further example of the difficulty of correctly identifying what a scale actually measures, as opposed to what researchers think or hope it measures, Combes and Gonzales (1994) state that self-concept is what people perceive them to be; it is what they believe about themselves. Conversely, self-report is what a person is willing or able to divulge, or what they can be induced into saying about self. Combes and Gonzales (1994) further suggest that what is often believed to be a measure of self-concept by researchers is actually a measure of self-report. Thus, for this research, in order to minimise the risk of students describing what they believed their parents wanted for them, students were reassured that responses given by them would be confidential, unless they indicated some sort of danger to themselves (e.g., self-harm).

Due to the low rate of consent form returns from the students of the selected schools, it was not possible to obtain the target sample size for this research. As the sample size was smaller than expected, the generalisability of the findings may be limited. To generalise the findings it would be highly desirable to administer the instrument to further, large samples.

Implications for Theory, Research, and Practice

Study 1 demonstrated that the SSQ possesses sound psychometric properties. Further, given that the SSQ has evolved from other survey instruments, which have undergone rigorous validation testing, it can be confidently used to investigate students’ science self-concepts in different disciplines of science, for science motivation and science aspirations. Clearly, science self-concept has been demonstrated to be multi-dimensional, thus advancing self-concept theory and research. In contrast, informing motivational theory and research, science aspirations were demonstrated to be domain general.

The newly developed SSDQ was based on the SDQII (Marsh, 1990), a survey instrument that has been shown to possess exceptionally strong psychometric properties (Flannery, Reise, & Widaman, 1995). The strengths of the SDQII lie in acknowledging that self-concept is not a uni-dimensional construct, but rather, is best represented as a multi-dimensional construct. Based on extensive research, Marsh
and Craven (2006) have suggested that research involving the self-concept is likely to be more useful when the multi-dimensional aspects of self-concept are accounted for. They further suggest that research is enhanced or improved when specific components of self-concept that are logically related to the aims of a particular study are utilised. As applied here, investigating students’ science self-concepts (i.e., how they view themselves as science students), is more likely to give insights into how students feel specifically about their science, as opposed to general, academic ability. Further, the results of Study 1 show that science self-concept can be conceptualised and explored at a level that recognises that science is multi-disciplined and that science self-concept is multi-dimensional. The results for this study suggest that the SSQ is also a psychometrically strong instrument for investigating secondary students’ self-concepts in different disciplines of science.

While students’ science self-concepts could be examined at the level of specific science disciplines, students were not able to distinguish between these disciplines for the constructs measured by the SMQ and SAQ. Given this finding, the scale items used for the SMQ and SAQ were not discipline specific, but rather related to science generally. CFAs showed the instrument to be psychometrically sound. Further, the CFA results for the SMQ and SAQ are consistent with the psychometric properties of the original instruments for science motivation, developed by Marsh, Craven, Hinkley, and Debus (2003), and those developed by Yeung and McInerney (2005) for science aspirations.

As its name suggests, CFA adopts a confirmatory approach, as opposed to an exploratory approach, where models are modified to obtain a good statistical fit. However, in a confirmatory approach minor modifications are permissible, and some were made to improve the model fit. These modifications are only possible when based on appropriate theoretical grounds (Byrne, 2006; Gerbing & Anderson, 1988; see also Chapter 5). The minor modifications made were performed not merely to yield a better model fit, but because there was appropriate justification for the modification. When modifications to a hypothesised model are made, Byrne (2006) suggests that the modified model should then be tested on another sample. As this was only a one-wave investigation, testing with another sample was not feasible with this research, due to constraints of time, resources, and other practical limitations. Testing with more samples is something that should be considered for future research.
The psychology and education literature is rich with strategies to improve educational and learning outcomes (e.g., Trigwell & Prosser, 1991). Further, the importance of self-concept in improving students’ achievement is well recognised (Marsh & Craven, 1997). The results of Study 1 show that the SSQ instrument has psychometrically sound properties. This means that the constructs measured by the SSQ can be used in other areas of educational or psychological research (such as Study 2), where such constructs are considered central to the research. For example, the SSDQ can be used to understand students’ science self-concepts in the different disciplines in science, and how they relate to other variables, such as overall school experience and students’ social and emotional well-being. Such information is very useful for schoolteachers, for understanding students’ interests, strengths, threats, and weaknesses in different domains of science. Measurement of science self-concepts can assist teachers to identify facets of self-concept that may be low and that could benefit from enhancement. Given that self-concept and performance share a dynamic and reciprocal relationship (Marsh & Craven, 2006) enhancing students’ science self-concepts can facilitate enhanced performance. So, if students have lower physics and chemistry self-concepts compared to their self-concepts in other science disciplines, further research could be undertaken to find out the reasons. For example, if it is the mathematical calculations in physics and chemistry that deter students from engaging in these subjects, it may be possible to help students by simultaneously developing their mathematical skills and enhancing their physics and chemistry self-concepts.

Similarly to the SSDQ, the constructs measured by the SMQ (motivation) (Yeung & McInerny, 2005) and the SAQ (aspirations) (Marsh et al., 2003) are recognised in education and psychology as important variables for understanding student learning. Examples of how the SMQ and SAQ can be used to better understand the student learning experience are provided in Study 2.

As students have to choose different science subjects for their HSC level, the information collected by administering this SSQ instrument could also be used by teachers and school counsellors, to assist students and parents to choose the most appropriate science subjects according to students’ interests, aspirations, and strengths. On the other hand, weaker students should be helped to build strong self-concepts in that particular discipline. For example, students with higher self-concepts in physics could be encouraged to pursue physics at the HSC level. Conversely, students with very weak self-concepts in physics could be helped to build their self-
concepts in physics, or they could be advised to select an alternative science discipline for the HSC. Furthermore, teachers, parents, and students can work together to enhance science self-concepts and skills in specific domains.

Utilising the SSQ to measure science motivation and aspirations could serve to identify and enhance students’ motivations and aspirations in science. This information could also be utilised by teachers to encourage more students to pursue careers in science. Hence, the SSQ has very important, valuable, and broad applications for the engagement of students in science disciplines.

Summary
The SSQ instrument demonstrates sound psychometric properties in investigating secondary students’ science self-concepts in different domains of science, science motivation, and science aspirations. While science self-concepts are domain specific, science motivation and aspirations do not appear to be. The findings of Study 1 are important in advancing theories of secondary students’ science self-concepts, motivation, and aspirations, and making available a new battery of psychometrically sound instrumentation to inform and advance theory, research, and practice.

Study 2: Explicating the Science Multidimensional Self-concepts, Motivation, Aspirations, and Achievement of Australian Secondary Students

Overview
Study 2 investigated the relations between a set of predictor variables (students’ science self-concepts, motivation), with aspirations and achievement, and follows logically from Study 1. A series of structural equation models were developed and tested in order to achieve this aim; the results of this are presented in Chapter 7. For each measurement scale of the SSQ, the general findings from the descriptive statistics are given, followed by a discussion of the MIMIC results. Finally, the results of SEM models are discussed.

Differences of Students’ Responses in Different Disciplines of Science
The differences in the science self-concept scores measured by the SSDQ were in the vicinity of small and medium in magnitude, according to Cohen’s $d$ effect size metric. General Science self-concept had the highest scores and Physics Self-concept
had the lowest scores. A possible reason why students’ General Science Self-concepts are strongest is that general science has a good balance with theory and experiments from all four disciplines of science. Biology Self-concept had the second highest score. This could be due to the relevance of the subject matter to students’ day-to-day life. Students experience the applications of biology in day-to-day life (e.g., medicine, learning about animals and plants). Students also may find physics difficult, due to the need to apply mathematical calculations and abstract concepts. This situation is further evidenced by the findings from the student focus groups in Study 3. Hence, Physics Self-concept was the lowest of all facets of science self-concepts.

The observation that chemistry and physics self-concepts are not as strong as self-concepts in other disciplines of science is consistent with the findings of Contractor (2004), who has reported that more PhDs are needed in chemistry, physics, and mathematics. Wood (2004) notes the number of graduates with PhDs in chemistry fell from 18 for every million people in 1969 to eight per million in 2003. Further, the number of students taking science in Year 11 and 12 in Australia has been falling steadily since 1976, and the proportion doing physics has almost halved.

Variation of Students’ Science Self-concepts across Gender and Age
The MIMIC test was conducted to determine whether students’ self-concepts in different disciplines of science varied across gender and stage of secondary schooling. The results in Chapter 7 show the MIMIC model to have good fit statistics. The results show secondary students’ self-concepts in general science, chemistry, and physics for males were stronger than those for females. This is consistent with the results of Study 3, which show that boys were generally more interested in chemistry and physics than were girls (e.g., St1, Year 10 from students’ focus groups).

The results in Chapter 7 indicate that students’ self-concepts in general science and biology increase with year level. One reason for this result could be that as students enter the senior level, they tend to drop the more difficult science subjects, such as physics and chemistry, in favour of biology and senior science. The school records available in this investigation showed that fewer students take physics and chemistry, compared to other science subjects. In Years 11 and 12, students were asked questions relating to their science self-concepts for all the different science
disciplines, irrespective of whether they were studying each discipline. It may be expected that they would have low self-concept scores for a science discipline that they were not studying in their senior years.

However, the strength of the Earth and Environmental Science Self-Concept did not increase as students get older. This finding is consistent with the observation that many students reported not pursuing earth and environmental science, as they thought that the discipline was not very relevant and applicable to their day-to-day life (see Chapter 8; St2, Year 10 from students’ focus groups). This supports another possible explanation why self-concept for a given science discipline generally increases with age: as the students grow older, they begin to understand the importance of their subject choice. Specifically, as they grow older, they appreciate that doing well in the subjects they have chosen has important implications, such as entry into university and career prospects.

**Differences in Students’ Responses to Different Types of Motivational Orientations**

The strongest motivation orientation of the SMQ is Mastery, followed by Intrinsic and Ego. These findings are consistent with the findings based upon students’ and teachers’ perceptions. For example, students are automatically motivated towards the subject if they are good at it and want to master the content (St1, Year 10 from students’ focus groups). Hence, lack of ability and lack of effort may contribute to students’ unsatisfactory performance and motivation (Hidi & Harackiewicz, 2000). According to McInerney et al. (2003), the salience and positive effect of mastery goals are relatively universal. Thus, the above finding is consistent with the available literature.

When students enjoy a subject they are more motivated to study the subject. Especially in somewhat harder subjects like science, students report enjoying the subject through practical experiments and chemical reactions such as explosions. Hence, intrinsic orientation also seems very important, and the next powerful tool in motivating students toward studying science.

Intrinsic Orientation scores were found to be higher than Ego Orientation scores. This could indicate that the joy of studying science (the intrinsic value) is more important than competing against other students. This is a positive finding, as researchers have demonstrated that intrinsic motivation produces more meaningful
learning, as opposed to learning simply in order to attain high grades (see Deci & Ryan, 1985; Kohn, 1998). Further, when discussing students’ learning experiences more generally, Aronson (2004) has shown very clearly that children perform better on objective exams, interact more positively with fellow students, and develop a greater liking for school when a cooperative approach is favoured over a competitive approach to learning.

According to the students’ responses, the weakest type of orientation in secondary students’ science motivation was ego. As science has a lot of basic concepts and principles that need to be comprehended by students, motivation due to competition among the students (i.e., ego orientation) can contribute minimally to student motivation, compared to mastery and intrinsic science motivation to study science.

Variation of Students’ Science Motivation across Gender and Age
The MIMIC model used to investigate students’ science motivation produced good model fit statistics. The results of this MIMIC model showed that students’ science motivation did not vary across gender and age. The results reveal that there is an interaction between gender and year level. The interaction effect indicates that females in higher years demonstrate moderately higher motivation in Mastery and Ego orientations. Hassan (2008) has shown that female students reported less anxiety than did male students in higher school years. Overcoming anxiety is a factor in achieving success for most students. Students who have less stress and are less anxious about studying science are more likely to be high achievers and to hold positive attitudes toward science (Atwater, Gardner, & Wiggins, 1995), and are therefore more likely to be motivated to pursue their studies in science. Based on these results, it is not clear why both males and females had almost an equal level of motivation in mastery in the lower year levels. Further, males in the lower school years demonstrated moderately higher motivation in ego orientation than did females, suggesting that younger males may be more competitive in science in comparison to females.

According to the results of the present investigation, there is no significant change of students’ science motivation in intrinsic orientation across students’ gender and year levels. However, different studies have shown that as children get older, their interests (i.e., related to intrinsic orientation) and attitudes toward
science, tend to deteriorate (Eccles & Wigfield, 1992; Hoffmann & Haussler 1998). Hence, further research is required to elucidate this issue.

**Differences in Students’ Responses across Disciplines of Science**

According to the mean scores for the aspiration measures, students’ Science Educational Aspirations are greater than that of their Career Aspirations in science (see Table 6.13). However, according to the Cohen’s effect size, the difference is small. This finding is consistent with the findings in the qualitative study (see Chapter 8). For example, a few students expressed that while they wanted to study science further, they did not want to have a career in science (St3, Year 10 from focus groups).

**Variation of Students’ Science Aspirations across Gender and Age**

The MIMIC model used to investigate students’ science aspirations produced good model fit statistics. While Schoon (2001) found that from a sample of students aged 16, boys had more career aspirations in science than girls, the results of Study 2 suggest that secondary students’ Science Educational and Career Aspirations in science did not vary across gender. Thus, students’ ambition to study science further and the selection of career in science was not determined by gender in the present investigation.

The results in Chapter 7 indicate that students’ Science Educational and Career Aspirations became stronger with year level at secondary school. This result is consistent with the findings of Yeung and McInerney (2005), who discovered that students’ aspirations through high school years declined from Years 7 to 9, but rose again in Year 11. Thus, as students get older, they usually focus more on their future careers.

**Variation of Students’ Achievement across Gender and Age**

As mentioned in the Chapters 4 and 5 students’ achievement in science was investigated through students’ (self) ratings and teacher ratings. MIMIC analyses did not show any significant differences between males and females for science achievement. This finding is consistent with Hackett, Betz, Casas, and Rocha-Singh (1992), who found that students’ achievement in engineering science did not vary across gender. However, Lee and Burkam (1996) found that boys in middle school
classes were better in physical sciences compared to girls, and that girls were better in biological sciences compared to boys.

MIMIC analyses did not show any significant differences across year levels for science achievement (as measured by student ratings and teacher ratings). Hence, perceptions of science achievement did not vary as a function of year level. The latter suggests that students’ and teachers’ ratings of achievement were not significantly different across year of schooling.

**Relations of Students’ Science Self-concepts with Science Aspirations and Science Achievement**

A series of SEM models were used to explore the relations between students’ science self-concepts and motivation and their science aspirations and achievement. Beta coefficients, correlations, and variance explained by SEM were used to assess the relations. The predictor variables were students’ gender, year level, and science self-concepts in different domains of science (i.e., general science, biology, chemistry, earth & environmental science, and physics). The outcome variables were Science Educational Aspirations and Career Aspirations. Both measures of aspirations were highly correlated ($r = .94$). This is to be expected, given that subject choice in school was largely influenced by students’ career aspirations. While highly correlated variables can potentially be problematic in statistical analyses, due to multicollinearity (see Chapter 5), when the variables are outcome variables, as is the case here, these problems do not occur.

The results of Study 2 show that for both Science Educational Aspirations and Career Aspirations, the predictive strengths of year and gender are either small or non-significant. Additional predictor variables (science self-concepts in different domains of science) were added to the initial predictor variables (i.e., year and gender) to see if a greater amount of variance in the outcome variables could be explained. Acceptable model fit statistics were produced. In this model (see Figure 7.4, in relation to Research Question 2.5.1) the total variances explained by the predictor variables (gender, year level, and science self-concepts) for the Science Educational Aspiration and Career Aspiration path models were 39.30% and 28.90% respectively (see Table 7.5). These values are much greater than the values obtained with year as the predictor variable (i.e., 5.4% and 4.7%), suggesting that students’ Science Educational and Career Aspirations are predicted better by science self-
concepts than by year level. Upon examining the correlation values given for year level in Appendix E with the respective beta values, no evidence was found of any suppression effects; this suggests that the given interpretation is relatively straightforward. Hence, with increase of year level, Science Educational and Career Aspirations increase. For the other two predictors, Biology Self-concept and Physics Self-concept, the associated beta coefficients differ markedly from the respective correlations, suggesting the possibility of suppression effects (see Table 7.4 and Appendix E). Whilst suppression is often a naturally occurring phenomenon within regression and SEM analyses, there are varying forms of suppression effect that need more careful consideration (e.g., negative suppression effects; Maassen & Bakker, 2001). Possible explanations for these suppression effects are discussed later in this section. Between Biology Self-concept and Physics Self-concept, Physics Self-concept was a stronger predictor of Science Educational and Career Aspirations.

The amount of total variance explained in teacher ratings by gender, year level, and science self-concept in the predictive path was 12.20%. Biology Self-concept was a significant predictor in this path. Thus, students’ achievement, based on teacher ratings, was predicted by students’ Biology Self-concepts. However, the prediction of teacher ratings by Biology Self-concept was not very high. As the beta coefficient and Pearson correlation values were similar to each other (see Table 7.5 and Appendix E), a suppression effect is unlikely to have been in play.

The total variance in student ratings of students’ achievement explained by gender, year level, and science self-concept in the predictive path was 50.50%. According to the results in Table 7.5, students’ General Science Self-concept was a significant predictor in this path. Hence, General Science Self-concept is a moderate predictor of student ratings. However, as the beta coefficient and Pearson correlation were markedly different (Table 7.5 and Appendix E) in this prediction, there may have been a suppression effect.

The observed suppression effects could be due to negative suppression and/or reciprocal suppression. Bodkin-Andrews, O’Rourke, and Craven (2010, see also Maassen & Baker, 2001) have suggested that ‘negative suppression’ (that is, where the beta coefficient is opposite to the corresponding correlation) may occur when the positive predictive power of one explanatory variable over an outcome is absorbed (or better accounted for) by a second explanatory variable predicting the same outcome. With this shared predictive variance portioned out of the original
explanatory variable, what may remain is negative explanatory variance, previously hidden by the positive explanatory variance (and possibly suggesting non-linear relations). Reciprocal suppression on the other hand is due to the sharing of information that is irrelevant, with outcome variables of the opposite orientation (Massen & Barkker, 2001). In this situation, when predictive variables are included in the regression equation, they suppress a part of each other’s irrelevant information.

The perceived suppression effects are possibly due to the moderately high correlation among the predictor variables, such as students’ science self-concepts. Practically speaking, it is possible that students’ science self-concepts in different domains are strongly inter-related and inter-connected through the subject content. As science is an integrated subject, similar concepts and principles are discussed across the different disciplines of science. As such, a moderately high positive correlation could be expected between students’ science self-concepts in different disciplines.

Relations of Students’ Science Motivation with Science Aspirations and Science Achievement

In the following analyses the predictor variables were students’ Gender, Year level, and science motivation (i.e., Mastery, Intrinsic, and Ego). The outcome variables were students’ Science Aspirations and Science Achievement. In Figure 7.5 students’ year level and gender were considered as the predictive variables, and the proposed model bears a good model fit. The total variances in Science Educational and Career Aspirations explained by year level and gender in the predictive paths were 5.40% and 4.70% respectively (Table 7.4). Hence, students’ year level was a significant predictor of Science Educational and Career Aspirations. The beta coefficients associated with the explained variance by year level in both Science Educational and Career Aspirations were approximately equal. As the associated beta coefficient and Pearson correlation were approximately equal (Table 7.4 and Appendix E) for these predictions, it could be assumed that there were no suppression effects. Hence, students’ Science Educational and Career Aspirations increase with year level. However, students’ gender was not a predictor of students’ Science Educational and Career Aspirations. In addition, both gender and year levels also were not predictors of students’ achievement in science, as represented by teacher and student ratings in the proposed path model.
Additional predictor variables (Mastery, Intrinsic, and Ego Orientations in science motivation) were added to the initial predictor variables (i.e., year and gender) to see if a greater amount of variance in the outcome variables could be explained. Excellent model fit statistics were produced. In this model (see Figure 7.6 of the Research Question 2.5.3) the total variances explained by year, gender, and science motivation in the predictive paths for Science Educational Aspirations and Career Aspirations were 37.60% and 31.10% respectively (see Table 7.6). These values are much greater than the values obtained only with year level and gender as the predictor variables (i.e., 5.4% and 4.7%). Hence, the results show that students’ science motivation was a better predictor of Science Educational and Career Aspirations than year level and gender. Year and Intrinsic Motivation were significant predictors in the above predictive paths. Intrinsic Motivation was a stronger predictor than year level in students’ Science Educational and Career Aspirations. As the associated beta coefficient and Pearson correlation were approximately equal for the predictions made by year level and Intrinsic Motivation (Table 7.6 and Appendix E), no suppression effects are likely to be occurring; hence, interpretation of the findings is straightforward. Students’ Science Educational and Career Aspirations become stronger as year level and intrinsic motivation increase.

In the same model, the amount of total variance explained in student ratings of students’ achievement by year, gender, and science motivation was 18.30%. The students’ Mastery, Intrinsic, and Ego Orientations in science motivation were significant predictors of student ratings, according to the associated beta coefficients. Hence, students’ abilities, enjoyment of the subject, and ego predicted their achievement in science. However, of the three orientations in this predictive path, the highest beta value was associated with Intrinsic Orientation. Hence, intrinsic motivation predicted students’ science achievement more than did other motivational orientations. As the beta coefficient and Pearson correlation values were markedly different (Table 7.6 and Appendix X) in these predictions, suppression effects are likely to have occurred.

The above suppression effects could also be due to negative and reciprocal suppressions. When two predictor variables—for example, students’ Mastery and Intrinsic orientations—correlate positively with each other, one of them (i.e., the suppressor) can receive a negative regression weight. Although the suppressor has relevant information in common with the outcome variable (i.e., student ratings) they
share fewer common elements than the common elements of irrelevant information shared by the suppressor and the other predictor. This situation results in negative suppression.

The above suppression effects are possibly due to the moderately high correlation of the predictor variables, such as students’ motivation in Mastery, Intrinsic, and Ego Orientations. Hence, students’ science motivation in Mastery, Intrinsic, and Ego Orientations can be strongly inter-related and inter-connected. For example, the items “I feel most successful in Science when I reach personal goals”, “I do Science because I enjoy thinking hard”, and “I feel most successful in Science when I do better than other students” represent Mastery, Intrinsic, and Ego Orientations respectively. Conceptually, these items are closely related. Thus, the factors in science motivation can overlap conceptually according to the students’ perceptions. Hence, suppression effects can occur in the above model in the context of the variables used.

**Strengths and Limitations of Study 2**

The MIMIC and SEM models used to investigate the relations of students’ science self-concepts and motivation with aspirations and achievement demonstrated good and acceptable model fits respectively. Findings should therefore be consistent with theory and previous research. Indeed, this is the case for Study 2. For example, Yeung et al. (2010) have reported that students’ science self-concepts tend to be domain specific, and Lynch (1991) found that students’ self-concepts play an important role in their aspirations. In other research, students’ self-concepts have been shown to influence academic achievement (Byrne & Shavelson, 1986; Hansford & Hattie, 1982; Purkey, 1970; Shavelson & Bolus, 1982; Taylor & Michael, 1991). The results of this present investigation also show that students’ science self-concepts are positively related with their aspirations and achievement.

The results of this study also reveal that students’ science motivation has positive relations with aspirations and achievement. In past research, Bank and Finlapson (1996) and John (1996) also reported that academic achievement is highly correlated with students’ motivation. Moreover, students’ motivation is believed to have a significant influence on learning outcomes (Martin, 2003; Martin, Marsh & Debus, 2001, 2003; McInerney, 1995; McInerney, Roche, McInerney, & Marsh, 1997; Pintrich & DeGroot 1990; Schunk 1990; Yeung & McInerney, 2005). Hence,
the results of this research are consistent with findings about the importance of students’ motivation in previous research. As Study 2 examined and confirmed, the relations of students’ science self-concepts and motivation with aspirations and achievement in different disciplines of science reliably and consistently, the results of Study 2 provide a strong and concrete foundation for future studies.

In order to test the relations between the factors reliably, it would be desirable to use a fully established survey instrument. According to Noar (2003), a survey instrument needs to be administered and tested many times over a considerable period of time, in order to fully establish its construct validity. The one wave nature of this investigation is therefore a limitation of the present study that could be addressed by future research. In particular, the analyses have been based on correlational data, rather than on the longitudinal data that would enable tests of causality. To test generalisability of the findings, it would be desirable and important to administer the instrument to a large sample size.

**Implications for Theory, Research, and Practice**

The findings of Study 2 make a valuable contribution to advancing theory and understandings about the relations of secondary students’ science self-concepts in different disciplines of science with science aspirations, motivation, and achievement. Clearly, students’ science self-concepts are positively related to their aspirations and achievement. Hence, it’s worthwhile that teachers consider structuring the learning experience so as to enhance students’ science self-concepts in specific domains of science. As stated by Burnett, Craven, and Marsh (1999), the enhancement of students’ self-concepts is a desirable educational goal in Australia and throughout the world. Similarly, science motivation predicts aspirations and achievement. Hence, enhancing students’ science motivation may facilitate improving science aspirations and achievement. The results also imply that both motivation and self-concept constructs serve as facilitators of desirable outcomes in science and are worthy of further investigation. In particular, longitudinal causal modelling studies would be useful to undertake, to test causality amongst these constructs over time and to explore the extent to which relations may be reciprocal.

The above relations may also be useful for science educators, for designing lessons and curricula to arouse curiosity and enhance enthusiasm in young science students. According to the results, students’ year level, Biology Self-concept, Physics
Self-concept, and Intrinsic motivation predict their Science Educational and Career Aspirations. Students’ Biology Self-concepts predict teacher ratings, while General Science Self-concepts, Mastery Motivation, Intrinsic Motivation, and Ego Motivation predict student ratings. These relations could be capitalised upon to promote science in schools. For example, the results of this study indicate that intrinsic motivation is a major predictor of students’ achievement (student ratings) and aspirations (Science Educational and Career) in science. Hence, teachers could consider making the subject more enjoyable and relevant to students’ lives, to enhance intrinsic motivation. Similarly, students’ science self-concepts could be enhanced simultaneously with skills. Thus, the use of the above findings in learning, teaching, and further research may help to promote science and counteract the decline of students enrolling in science.

Summary
The proposed models for the investigation of relations of students’ science self-concepts and motivation with aspirations and achievement in science demonstrate sound psychometric properties. In general, students’ science self-concepts and science motivation are positively related with science aspirations and science achievement. Specifically, students’ Biology Self-concept, Physics Self-concept, and Intrinsic Motivation are sound predictors of their Science Educational and Career Aspirations. Moreover, students’ Biology Self-concepts are a significant predictor of students’ achievement, according to the teacher ratings, whereas students’ General Science Self-concepts are a significant factor in predicting students’ achievement according to student ratings. These findings suggest that desirable outcomes such as students’ science aspirations and achievement may be facilitated by enhancing their science self-concepts and motivation.

Study 3: A Qualitative Examination of the Associations between Australian Secondary Students’ Science Self-concepts, Motivation, Aspirations, and Achievement

Overview
The results of the qualitative study were presented in Chapter 8. The aim of this section is to explicate findings from the student focus groups and teacher interviews
in relation to the broader aims of this investigation. Specifically, the discussion focuses on insights gained from teachers and students that elucidate reasons why secondary school students’ uptake of science is declining and, most importantly, some possible solutions to this problem. While there was considerable overlap in the insights provided by both students and teachers in data triangulation, each group offered additional insights that were unique to them. The findings unique to students and teachers are given first under separate headings, followed by a longer discussion on the points raised by both students and teachers.

**Student Perceptions**

The results of Study 3 suggest that students have definite opinions about science both as a subject at school (compulsory until year 10), and as a field of knowledge that has relevance outside of their school lives. In general, students with strong science self-concepts, high motivation, greater aspirations, and sound achievement in science possess very positive attitudes towards the subject, compared to students who have weak science self-concepts, low motivation, low aspirations, and poor achievement. This is not surprising, given the items of the SSDQ that were used to differentiate students with high science self-concepts from students with low science self-concepts. According to students, the factors affecting their decision to undertake and continue science subjects at high school level, included enjoyment of the subject, the particular discipline of the subject (e.g., physics, biology, etc.), and the Australian Tertiary Admission Rank (ATAR).

**Enjoyment of science.** Students who enjoy science are more likely to be actively engaged in studying it, and to wish to continue studying it at higher levels. Students with high science self-concepts enjoyed science subjects more than did students with low science self-concepts. With the ever-increasing emphasis being placed on being competitive and on pursuing high marks, it is easy to forget that science can be enjoyable. Enjoyment is closely related to intrinsic motivation. According to Ryan and Deci (2000), intrinsic motivation reflects the natural human propensity to learn and assimilate. Thus, ensuring that science is more enjoyable is likely to attract more students to science and to result in meaningful learning. Science is typically viewed as a difficult subject. This perception has been identified in this research as a reason that deters students from choosing it as a subject to learn at school or university, as well as from pursuing a career that is science focused.
However, the difficult nature of science can be addressed to some degree by making the subject more enjoyable. ‘Difficult’ and ‘enjoyable’ are not mutually exclusive. An activity does not have to be easy in order for it to be enjoyable. For example, students often engage in other activities (such as sports, dance) that are difficult, which they do however find intrinsically motivating or rewarding (e.g., see self determination theory by Deci & Ryan, 1985). Science can be made more enjoyable by using hands-on experiments, excursions, group work, and research projects. Further, given quantum advances in information technology, there is huge potential for computer assisted learning to play a role in making science more enjoyable for students.

**Different disciplines of science.** The disciplines of science were perceived differently by students in terms of relevance, importance, enjoyment, and difficulty. Many students believed that chemistry and physics are difficult, compared to biology and earth & environmental science. This is due to the abstract nature of many of the basic concepts and principles (Allen & Duch, 1996) in chemistry and physics, and the involvement of mathematical calculations in these two subjects. For example, concepts like atoms, molecules, and moles are abstract in nature, and students need somewhat deeper thinking in order to understand these concepts. This is in stark contrast to biology, where students can see, touch, and feel the samples and specimens. Mostly physics and chemistry were enjoyed by students with high self-concepts. Students with low science self-concepts were interested mostly in biology. With an understanding of this situation, science teachers and educators can design and plan the science curriculum and its delivery, to make these disciplines more appealing to students. For example, for physics and chemistry, teachers can use computer software programmes with relevant illustrations and simulations, to teach concepts that are more abstract in nature and to enhance students’ understanding and interest.

While students deemed biology an easier subject, as described in the previous paragraph, many believed that its content was excessive and needed to be reduced. The problem with this excessive content of biology could be addressed by focusing on basic principles and concepts in biology, rather than further pursuing related concepts; that is, to reduce scope whilst maintaining depth. Perhaps some biology topics could be absorbed in biology-related subjects such as personal development, health, and physical education (PDHPE) and senior science.
Students considered that the use of the knowledge and theories behind earth & environmental science were of limited value. They also had the opinion that there are not sufficient career opportunities in the earth and environmental science field. These findings suggest that students may benefit from learning more about the employment opportunities in this field and the practical applications of this field of science, to attract and engage more students in this subject discipline.

Australian Tertiary Admission Rank (ATAR). Students reported that they found assessment procedures in science more difficult than those for non-science subjects. The ATAR influences what subjects high school students choose. As students need an ATAR score that will permit them entry into the course they wish to pursue at the tertiary level, they believe that selecting easier subjects, rather than selecting more difficult subjects, will increase their ATAR. Hence, there is a trend to drop science subjects, in the expectation that easier subjects will achieve the same or a better outcome—namely, entry into university. A problem with this is that students who may be interested in science end up not choosing science subjects. To overcome this problem, teachers and science educators can encourage students to pursue those subjects they find most interesting, and not what they believe are the easiest subjects. As expressed by Koballa and Crawly (1985; 2010), planning is required to develop positive attitudes toward science.

Teacher Perceptions
According to teachers, the factors affecting students’ decision-making process in relation to pursuing science are: student achievement, parents’ expectations and family influence, peer pressure, the difficulty of the subject, financial reward, declining enthusiasm towards science, and teaching methods. Science teachers also believe that they are not financially rewarded enough to encourage them in promoting science in schools. Teachers also had the perception that they need more teacher training programmes, to make science teaching more efficient and effective in schools, and that science should be promoted both inside and outside the school via reliable media.

Students’ science achievement. Teachers reported that students who perform better enjoy the subject and like to continue with the subject in the senior years. When it is seen as an enjoyable subject, students are motivated and inspired to engage in science.
Parents’ expectations, family influence, and peer pressure. Parents’ expectations and family influence also play a significant role in students’ enrolment in science. Some parents urge their children to undertake science as they themselves work in a science-related job. Some teachers have suggested that parents, especially those from an Asian background, want their children to undertake science and become professionals, like medical doctors and engineers. Parental involvement has a positive effect on students’ academic achievement (Fan & Chen, 2001). Hence, support and encouragement by parents at home could influence students to further engage with science. Moreover, students with brothers and sisters undertaking science tend to also proceed with studies in science.

Peer pressure. Teachers advised that students are naturally very close to their peers and thus, they tend to imitate what their peers do. Teachers noted that students select science when their friends also select science for their HSC level. Thus, a future strategy may be to popularise science among students through group work and project work where students could work together and enjoy their learning. In this way, science teachers could plan their lessons to build inter-relations among the students that would benefit students in engaging science and enjoying science, in order to develop a positive attitude towards science that would attract more students.

Difficulty of the subject. Teachers reported that the perceived difficulty of science in comprehending and applying subject matter, compared to many other subjects, reduces students’ interest in science. As science involves learning scientific concepts and principles, it needs a higher level of achievement in the taxonomy of Bloom's educational achievement hierarchy level (Cruz, 2004). Thus, teachers and other science educators could work together to minimise perceptions of the difficult nature of the subject through devising effective teaching and learning strategies to make science more engaging and easier to understand, so as to prevent students from leaving science disciplines at the HSC level.

Declining enthusiasm for science. Teachers reported that there is a significant downward trend in students’ enthusiasm for the subject science over the high school years. They reported that Year 7 students have a lot of enthusiasm, ambitions, and hopes in relation to science. However, their enthusiasm is diminished and destroyed gradually in the following years, due to many inter-related factors such as: the difficulty of the subject, the subject becoming less practical and therefore less enjoyable, the complex nature of the concepts and principles to be learnt, the
increased amount of content, and by their own poor performance. Pill and Farvis (2001) also found that students’ enthusiasm for science declines progressively with age. Thus, teachers suggest that educators have to be proactive, to establish and maintain students’ interest in and enthusiasm about science, to attract more students choosing science at senior year levels in high school.

**Teaching methods.** Teachers also believed that teaching methods affect students’ perceptions about science and their understanding of scientific concepts and principles. Goldhaber and Brewer (1996) expressed the view that teacher characteristics do appear to make a difference to student performance. Hence, teachers with higher pedagogical skills can inspire students in science through appropriate teaching methods. Teachers also suggested that they would benefit from more professional development training, in order to enhance student engagement with science.

**Financially not rewarding.** Teachers stated that even students who study science and choose a career in science are not rewarded financially, compared to students who pursue their studies in disciplines perceived to be easier. Thus, teachers suggested that in order to promote and popularise science among students, careers in science need to be made more financially rewarding, to attract students.

Teachers also suggested that science teachers should be financially rewarded and promoted due to the difficult nature of the subject and to the specialised knowledge required to teach science effectively. Teachers suggested that they worked harder and sacrificed more than did teachers in other disciplines. They believed that a suitable reward system was needed, one that recognises the unique challenges of teaching science. Teachers felt that this would result in benefits for the students.

**Teacher training programmes.** Teachers believed that the Department of Education and Communities should conduct more teacher training courses, introducing new science teaching methods using recent advancements in technology, in order to promote effective science teaching and to enhance students’ science comprehension. Highlighting the importance of teacher training programmes, Gibbs and Coffey (2004) reported a range of positive changes in teachers from these training programmes. Science teachers also felt that more refresher training courses utilising new technology would help enhance the quality of their teaching. They also suggested that there was a need for further infrastructure facilities such as laboratory
spaces to enable the conduct of more practical work, to arouse the students’ curiosity and to develop their enthusiasm for the subject.

**Promoting science outside the school.** Teachers also suggested that science should be promoted not only in schools but outside school, via television, newspapers, and student research projects. They felt that this would promote the public face of science and therefore would encourage students to take up science in schools.

**Common Perceptions of both Students and Teachers**

Factors influencing students’ engagement with science include: enjoying science, the experimental nature of science, the relevance of the subject matter to everyday life, having effective and efficient teachers, career opportunities, and the amount of subject content.

**Enjoying science, experimental nature, and the relevance to day-to-day life.** Many students reported enjoying science as it provides them with fun experiences and arouses curiosity. Since science is an experimental subject, it is possible to perform colourful and attractive experiments in order to explain the theories behind the subject. Students reported that they wanted to perform more practical experiments in science, as they found these enjoyable. They also reported that they felt that science could be made more clearly relevant to their day-to-day lives and therefore more meaningful to them.

**Teacher characteristics and amount of subject matter content.** Science has concepts and principles that range from simple to very complex and abstract. Thus, not surprisingly, students often reported that science is more difficult compared to other subjects. Hassan and Treagust (2003) suggest that teacher characteristics are very important in making science more enjoyable and easy. Teachers are very important and valuable agents in promoting subject science in schools (Hall, 2012). Hence, students suggested that better quality teachers in science would enhance their participation in science.

Both teachers and students had the opinion that some science subjects, like biology and chemistry, have too much content. Hence, teachers and students suggested cutting theory content and increasing the practical component, for more hands-on experience, in order to attract more students to study science at HSC level.
Career opportunities. Some students and teachers remarked that science does not have as many career opportunities as do other subjects. This is true for some disciplines of science, such as pharmacology and earth & environmental science. However, there are many opportunities for science students in Australia in the fields of medicine, engineering, and scientific research. It would seem useful to promote the career opportunities available to students. For example, according to Lane and Puddy (2012), although 4,500 agricultural jobs were advertised in 2010, Australia has produced only 743 graduates in agricultural science.

Strengths and Limitations of Study 3
The conduct of 17 student focus groups, including both high and low self-concept students, and 11 teacher interviews with teachers who teach different disciplines of science, enriched and provided insights into this investigation that are not easily obtainable from quantitative methodologies. Several factors that influence students in engaging in high school science were identified: science self-concepts, lack of student interest, inadequate teaching methods, etc. As both teachers and students had many similar opinions about science, the findings demonstrate high trustworthiness and reliability. These findings complement and add to the findings from previous studies.

Due to time constraints, the student focus groups and teacher interviews were semi-structured and of short duration (average time 30-40 minutes). Hence, longer, more open-ended interviews would be desirable for future research, to further explore the issues identified in more depth. In addition, future research could benefit from conducting focus groups and interviews with a larger sample size, to further elucidate the generalisability of the findings.

Implications for Theory, Research, and Practice
The research findings in Study 3 make a valuable contribution to advancing theory and knowledge by providing students’ and teachers’ perceptions about issues in science education at the secondary school level as they pertain to declining student enrolments. Students and teachers identified a number of barriers to studying science, and a number of proposed solutions were offered. Hence, the results of the study have important implications for policy and practice.
The results also imply that quality teaching in science is critical, with teachers needing to ensure that science is more relevant, understandable, and enjoyable for students. In order to accomplish this, teachers suggested that they would benefit from more professional development courses and from financial rewards for quality teaching in science.

**Summary**

Students and teachers expressed what they believe is important in promoting and uplifting science in schools. Significant factors that influenced secondary students’ science education at school were identified, and in particular the following: student enthusiasm, enjoyment of science, exposure to experiments, manageable level of subject content, clearly understanding the principles and concepts, relevance of the subject matter to real life, effective and passionate teachers, appropriate and adequate teaching methods, students’ mathematical skills, career opportunities, and media influences. Students with high science self-concepts, motivation, and aspirations viewed science as an enjoyable, important, and useful subject, while most of the students with low science self-concepts, motivation, and aspirations identified science as not enjoyable, highly difficult, and less useful to their lives. Thus, although they clearly viewed them differently, both groups of students, those with high and those with low science self-concepts, motivation, and aspirations, identified the above factors as important.

**Chapter Summary**

The results of three interrelated studies have been discussed in this chapter. The results of Study 1 reveal that the SSQ instrument has sound psychometric properties for investigating secondary students’ science self-concepts in different domains of science, science motivation, and science aspirations. It also confirms that science self-concepts are domain specific, while science motivation and aspirations are not.

In Study 2 students’ year level, Biology Self-concept, and Physics Self-concept were found to be significant predictors of their Science Educational and Career Aspirations. Moreover, students’ Biology Self-concept was a significant predictor of their achievement according to teacher ratings, whereas students’ General Science Self-concept was a significant factor in predicting their achievement according to students’ ratings. Intrinsic motivation was also found to be a predictor
of students’ Science Educational and Career Aspirations. All three types of orientation, Mastery, Intrinsic, and Ego were significant predictors of students’ achievement according to student ratings. Findings from the qualitative study further enriched the findings. According to the perceptions of teachers and students, key features that influence and enhance secondary students’ science education at high school include the following: students’ enthusiasm, their enjoyment of science, exposure to experiments, manageable level of subject content, clear understanding of the principles and concepts, perceived relevance of the subject matter to real life, the presence of effective and passionate teachers, of appropriate and adequate teaching methods, students’ mathematical skills, supportive influence from the media, the existence of an appropriate reward system for science teachers, and career opportunities in science. These findings have significant implications for the urgent and important task of promoting secondary science, and for addressing declines in student science enrolments.
CHAPTER 10

CONCLUSION

There is nothing which can better deserve our patronage than the promotion of science and literature. Knowledge is in every country the surest basis of public happiness (George Washington).

Chapter 1 introduced the rationale and aims of this research study. According to the available literature, though the importance of science is well recognised, the uptake of science by high school students is decreasing. This situation is critical, especially in developed countries such as the United States of America, the United Kingdom, Germany, and Australia. This decline has resulted in a lack of suitably qualified workers in science-related professions and threatens the success of the Australian economy. Though this issue has been discussed repeatedly in the media, by politicians and by academics, the problem would appear to be getting worse. Researchers have been trying to investigate and understand this situation. They have reported that students’ academic abilities, interest and motivation, in addition to teaching methods, are significant factors that influence whether or not students will engage in science subjects at school. Science as a subject comprises different disciplines, such as: biology, chemistry, earth & environmental science, and physics. Building on the work of Marsh and Craven (2006), this study acknowledges the multidimensional structure of science and has examined psychological aspects of students, such as their science self-concepts, motivation, aspirations, and achievement. This research used a mixed-methods design comprising two quantitative studies and a qualitative study.

1Retrieved from http://www.goodreads.com/quotes/18436-there-is-nothing-which-can-better-deserve-our-patronage-than
The aim of Study 1, the first of two quantitative studies, was to develop and assess the psychometric properties of the SSQ. The results showed that the individual scales and the overall instrument possessed sound internal consistency reliability and strong and robust structural validity. Further invariance was demonstrated across gender and year level. This advances self-concept theory and research in demonstrating that science self-concept is a multi-dimensional construct. It was also demonstrated that motivation is a domain general construct; this adds to our knowledge of research in motivational theory. Overall, the creation of a psychometrically sound new measure of secondary students’ science self-concepts, motivation, and aspirations makes available to researchers and educators a new battery of instrumentation to further advance theory, research, and practice in science education.

Study 2 used MIMIC models and SEM to investigate students’ science self-concepts and motivation, and explored their relations to aspirations and achievement in science. The results showed that students’ science self-concepts in general science, chemistry and physics were stronger for males, while self-concepts in general science and biology became stronger with advancing year of secondary schooling. The females in higher school years demonstrated moderately higher science motivation in mastery orientation than males. However, in the lower years, males demonstrated moderately higher motivation in ego orientation than did females. The results also showed that students’ year level and intrinsic motivation in science were significant predictors of students’ educational and career aspirations in science, and that intrinsic motivation was a stronger predictor than year level in students’ aspirations in science. Mastery and ego motivation were also found to be significant predictors of student ratings of achievement in science.

Study 3 was qualitative, and supported and enriched the findings from Studies 1 and 2. For example, whilst the results of Study 2 revealed that students’ intrinsic motivation was a strong predictor of their science educational and career aspirations in science, both students and teachers confirmed this finding by stating the importance of enjoying science in order to choose to continue to study it. Key themes identified as assisting students to engage with and pursue science included: teacher enthusiasm, enjoyment of science, participation in experiments, manageable level of content, and being taught in such a way as to be able to clearly understand the subject matter. Furthermore, effective and passionate science teachers were
identified as a crucial factor in influencing secondary students’ decision to undertake science subjects at school. Conversely, a lack of practical orientation in teaching sessions, having a poor understanding or misunderstanding of the basic concepts and principles in science, the perceived irrelevance of subject matter to real life experiences, high level of content and higher difficulty of subject content, inadequate mathematical skills, ineffective and inefficient teachers and inappropriate and inadequate teaching methods, were all identified as factors that deter students from science. As the ATAR is important in obtaining opportunities for university education, students indicated that they selected “easy” subjects and avoided more difficult subjects, like science, to maximise their chances of getting a high ATAR. Science was frequently referred to as a difficult subject. Moreover, students believed that science assessments were more difficult than assessments in other subjects. In general, students also expressed the belief that there are not enough career opportunities in the field of science in Australia and that these careers are not adequately renumerated. Students reported that their interest in different science disciplines, their aspirations in science and the relevance of science subject content to day-to-day life, were some of the determinants of their decision-making process in regard to continuing science education at post-secondary level. These factors all affect students’ decision-making process.

The results of Study 2 showed that there are positive relations between students’ science self-concepts and motivation, and their aspirations and achievement in science. Students with high self-concepts in science had stronger intentions of following science courses in their further education than did students with low science self-concepts. Furthermore, students’ achievement in science was typically greater for students with high science self-concepts than for students with low science self-concepts. The findings from the student focus groups indicate that students who are highly motivated towards science have strong intentions to pursue careers in science and do better in science than students who are less motivated.

Teachers also had very valuable ideas, attitudes, and observations about science education practices within schools in Australia. They reported that students’ performance, interests and career aspirations, parents’ expectations, teacher characteristics, the difficulty of the subject, and the relevance of the subject to day-to-day life, are all key factors that influence students’ decision-making process in relation to their school studies. Moreover, students’ experience in their academic life,
their career aspirations and interest in the subject, in addition to teachers’ influence, family influences, the perceived lack of financial rewards, and peer pressure, are key aspects informing the decision-making process in relation to continuing and pursuing science at post-secondary level.

In nature everything has both quality and quantity providing multiple ways of looking at something. Hence, the mixed methods approach used in this study has provided both a quantitative and qualitative perspective to understanding students and their experiences with science. Use of both these perspectives has enabled a triangulation of findings in order to give greater confidence in the results.

Science as a school subject needs to be promoted, by addressing the related barriers appropriately. The identified barriers to promoting better uptake of science in schools, according to teachers’ perceptions, included: the difficulty of science subjects, inadequate teaching methods, the lack of suitable and enough career opportunities in science in Australia, the intensive science curricula, the lack of adequate in-service teacher training, the lack of financial rewards for science teachers, and inadequate support from the media. However, teachers reported that students come to Year 7 science classes with much interest, curiosity, hope, and enthusiasm. However, in the years that follow, their motivation and enthusiasm for science deteriorate. Factors contributing to this decline include the perceived lack of relation between the subject matter and real life situations, the difficulty of the subject, a lack of enjoyment in learning science, and inadequate support from the home environment. These findings have important implications for theory, research, and practice.

The newly developed instrument battery provides an innovative and robust measure to advance theory, research, and practice in the future. Moreover, the results and findings of this investigation suggest that enhancing students’ science self-concepts and motivation would be invaluable. This could be a profitable avenue for future research. Further, providing teachers with professional development training to assist them to motivate and engage students in science may yield substantial benefits. It would also seem that the science curriculum could benefit from revision, to decrease the amount of content covered and to increase the inclusion of practical work that engages students and helps them to perceive science as relevant to their lives. These issues must be addressed with a sense of urgency, to ensure that science
is advanced in this country for a better tomorrow. Preparing now, can save us from repairing, long into the future.
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APPENDIXES
Appendix A
Secondary Science Questionnaire

Purpose

The purpose of this survey is to help to find out about your background, your education and yourself. Your participation in the study is voluntary and you can withdraw from the study at any time. Not participating in the study will not affect your relationship with your school.

This is not a test. There are no right or wrong answers and everybody will have different answers. Just make sure that your answers show what you really think about yourself. It will be explained to you how to answer each question. There are some questions that seem the same. This is not a trick. It is just that this type of survey needs to ask questions in slightly different ways. Just answer them in a way that shows what you really think about yourself. Please read each question carefully and answer as accurately as you can. In the questionnaire you will need to tick or circle your answers for most questions. For a few questions you will need to write a short answer.

Your answers will only be seen by the researchers and will not be shown to anyone in your school or your community. The researchers will remove the consent form you sign below and store this separately. The research team will not report the names of any students or schools that participate in the study.

Student Consent

Student Consent Form to Participate in the Research Study

First Name: ______________________________
Surname: _________________________________
School: _________________________________

I agree to participate in the study

Signature: _________________________________
Date: _________________________________
## ABOUT YOU

1. **What year of school are you in?**  
   ________________

2. **Which of these science subjects do you do? (tick all that apply)**
   1. Year 7-10 General Science
   2. Biology
   3. Chemistry
   4. Physics
   5. Earth & Environmental Science
   6. Senior Science (Year 11 & 12)

3. **On what date were you born?**
   _____   _____   ______  
   Day   Month   Year

4. **Are you female or male?**
   1. Female
   2. Male

5. **What language do you speak at home most of the time?**
   1. English
   2. Chinese
   3. Arabic
   4. Vietnamese
   5. Turkish
   6. Other - Please specify:  
      _____________________
6 Which of the following do you have in your home?
(Please tick as many boxes that apply to you)

1 □ A desk to study at
2 □ A room of your own
3 □ A quiet place to study
4 □ A computer you can use for school work
5 □ Educational software
6 □ A link for internet
7 □ Your own calculator
8 □ Classic literature (e.g., Shakespeare)
9 □ Books of poetry
10 □ Works of art (e.g., paintings)
11 □ Books to help with your school work
12 □ A dictionary
13 □ A dishwasher

7 Please state whether or not you intend to continue to study science at school.

1 □ Yes
2 □ No
8. Please state whether or not you intend to continue to study science at TAFE.

1 □ Yes
2 □ No

9. Please state whether or not you intend to continue to study science at University.

1 □ Yes
2 □ No

Please read the following paragraphs carefully before answering the rest of the questions in this questionnaire:

- **Biology** is one of the subject areas of science in which we study about living matter such as plants, animals and their habitats.

- **Chemistry** is another subject area of science in which the basic emphasis is on chemical elements, compounds, structures (atoms, molecules, ions, lattices etc.), reactions and uses of matter.

- **Earth & Environmental Science** is yet another subject area of science where we study about the whole universe, paying special attention to the earth. In this area we study about rocks, life in the past, dynamic earth, space travel, planets and stars.

- **Physics** is an area of science where we study different types of energy (electricity, sound, heat, mechanical etc.), forces (magnetic, gravitational etc.) and their uses.

10. In the following subject areas how would you rate yourself as a student?

<table>
<thead>
<tr>
<th></th>
<th>Poor</th>
<th>Not Very Good</th>
<th>Good</th>
<th>Very Good</th>
<th>Excellent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science (Overall)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Biology</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Chemistry</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Earth and Environmental Science</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Physics</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
11 In the following subject areas how do you think your teacher would rate you as a student?

<table>
<thead>
<tr>
<th>Subject</th>
<th>Poor</th>
<th>Not Very Good</th>
<th>Good</th>
<th>Very Good</th>
<th>Excellent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science (Overall)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Biology</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Chemistry</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Earth and Environmental Science</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Physics</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

12 Do you wish to work in a job related to science?

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definitely Not</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probably Not</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maybe Not</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Maybe Yes</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probably Yes</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Definitely Yes</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This is a chance for you to look at how you think and feel about yourself. It is important that you are honest and you give your own views about yourself, without talking to others. On the following pages are a series of statements that are more or less true (or more or less false) descriptions of you. Please use the following six-point scale to indicate how true (or false) each item is as a description of you. Respond to the items as you now feel even if you felt differently at some other time in your life. Use the following six-point scale to indicate how true (like you) or how false (unlike you), each statement over the page is as a description of you. Please do not leave any statement blank. Do not say your answer out loud or talk about it with anyone else.

Below are a couple of example questions.

1. I like to read comic books.  

Bob circled 6 for “True”. This statement describes me well; it is very much like me”. This means that he really likes to read comic books. If Bob did not like to read comic books very much, he would have circled 1 for “Definitely False. Not like me at all; it isn't like me at all” or 2 for “Mostly False”.

2. In general, I am neat and tidy.  

Bob circled 4 for “More true than false” because he is not very neat, but he is not very messy either.
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>False</th>
<th>Mostly False</th>
<th>More False than True</th>
<th>More True than False</th>
<th>Mostly True</th>
<th>True</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I am good at <strong>SCIENCE</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td><strong>BIOLOGY</strong> is one of my best subject areas</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>I often need help in the subject area <strong>BIOLOGY</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td><strong>CHEMISTRY</strong> is one of my best subject areas</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td><strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong> is one of my best subject areas</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td><strong>PHYSICS</strong> is one of my best subject areas</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>I do badly in tests of <strong>SCIENCE</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>I look forward to <strong>PHYSICS</strong> classes</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>I have always done well in <strong>SCIENCE</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>I have trouble understanding anything with <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong> in it</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>11</td>
<td><strong>SCIENCE</strong> is one of my best subjects</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>I enjoy studying for <strong>PHYSICS</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>I am good at <strong>BIOLOGY</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>14</td>
<td>I do badly in tests of <strong>CHEMISTRY</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>15</td>
<td>I am good at <strong>CHEMISTRY</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>16</td>
<td>I am good at <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>17</td>
<td>I have always done well in <strong>BIOLOGY</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>18</td>
<td>I never want to take another <strong>PHYSICS</strong> course</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>19</td>
<td>I have always done well in <strong>CHEMISTRY</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>20</td>
<td>I have always done well in <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
### WHAT HELPS YOU DO WELL IN SCIENCE

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>False</th>
<th>Mostly False</th>
<th>More False than True</th>
<th>More True than False</th>
<th>Mostly True</th>
<th>True</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I feel most successful in <strong>SCIENCE</strong> when I reach personal goals</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>I do <strong>BIOLOGY</strong> because I like learning new things</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>I feel most successful in <strong>CHEMISTRY</strong> when I really improve</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>I do <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong> because I enjoy thinking hard</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>I feel most successful in <strong>SCIENCE</strong> when I really improve</td>
<td>1</td>
<td>2</td>
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<td>5</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>I do <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong> because I like to solve hard problems</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>I feel most successful in <strong>PHYSICS</strong> when I do better than other students</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>I do <strong>BIOLOGY</strong> because I enjoy thinking hard</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>I feel most successful in <strong>CHEMISTRY</strong> when I work to the best of my ability</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>I do <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong> because I enjoy trying to understand new things</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>11</td>
<td>I feel most successful in <strong>PHYSICS</strong> when I show other students that I am the best</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>I feel most successful in <strong>SCIENCE</strong> when I work to the best of my ability</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>13</td>
<td>I do <strong>BIOLOGY</strong> because I like to solve hard problems</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>14</td>
<td>I feel most successful in <strong>CHEMISTRY</strong> when I do something I could not do before</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>15</td>
<td>I feel most successful in <strong>PHYSICS</strong> when I do something others cannot do</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>16</td>
<td>I feel most successful in <strong>SCIENCE</strong> when I do something I could not do before</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>17</td>
<td>I do <strong>BIOLOGY</strong> because I enjoy trying to understand new things</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td></td>
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<td>False</td>
<td>Mostly False</td>
<td>More False than True</td>
<td>More True than False</td>
<td>Mostly True</td>
<td>True</td>
</tr>
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</tr>
<tr>
<td>18</td>
<td>I feel most successful in <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong> when I do better than other students</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>19</td>
<td>I feel most successful in <strong>PHYSICS</strong> when I know more than other students</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>20</td>
<td>I do <strong>CHEMISTRY</strong> because I like learning new things</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>21</td>
<td>I feel most successful in <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong> when I show other students that I am the best</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>22</td>
<td>I do <strong>SCIENCE</strong> because I like learning new things</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>23</td>
<td>I feel most successful in <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong> when I do something others cannot do</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>24</td>
<td>I feel most successful in <strong>PHYSICS</strong> when I reach personal goals</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>25</td>
<td>I feel most successful in <strong>BIOLOGY</strong> when I do better than other students</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>26</td>
<td>I do <strong>CHEMISTRY</strong> because I enjoy thinking hard</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>27</td>
<td>I feel most successful in <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong> when I know more than other students</td>
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Thank you for participating in this survey
**BREAKDOWN OF MEASURES**

Below the numbers in the left hand column are the serial numbers. The numbers in the second column are the corresponding numbers to the survey.

**Statements of the student questionnaire on Self-Concept: adapted from SDQII**

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<tbody>
<tr>
<td>9</td>
<td><strong>CHEMISTRY</strong> is one of my best subject areas</td>
</tr>
<tr>
<td>10</td>
<td>I do badly in tests of <strong>CHEMISTRY</strong></td>
</tr>
<tr>
<td>11</td>
<td>I am good at <strong>CHEMISTRY</strong></td>
</tr>
<tr>
<td>12</td>
<td>I have always done well in <strong>CHEMISTRY</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>EARTH &amp; ENVIRONMENTAL SCIENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td><strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong> is one of my best subject areas</td>
</tr>
<tr>
<td>14</td>
<td>I have trouble understanding anything with <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong> in it</td>
</tr>
<tr>
<td>15</td>
<td>I am good at <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong></td>
</tr>
<tr>
<td>16</td>
<td>I have always done well in <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong></td>
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<table>
<thead>
<tr>
<th></th>
<th>PHYSICS</th>
</tr>
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<tbody>
<tr>
<td>17</td>
<td><strong>PHYSICS</strong> is one of my best subject areas</td>
</tr>
<tr>
<td>18</td>
<td>I look forward to <strong>PHYSICS</strong> classes</td>
</tr>
<tr>
<td>19</td>
<td>I enjoy studying for <strong>PHYSICS</strong></td>
</tr>
<tr>
<td>20</td>
<td>I never want to take another <strong>PHYSICS</strong> course</td>
</tr>
</tbody>
</table>
Statements of the Questionnaire on Student Motivation (Marsh et al, 2003)  
(Mastery, Intrinsic and Ego orientations)

<table>
<thead>
<tr>
<th></th>
<th>SCIENCE MOTIVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I feel most successful in SCIENCE when I reach personal goals</td>
</tr>
<tr>
<td>2</td>
<td>I feel most successful in SCIENCE when I really improve</td>
</tr>
<tr>
<td>3</td>
<td>I feel most successful in SCIENCE when I work to the best of my ability</td>
</tr>
<tr>
<td>4</td>
<td>I feel most successful in SCIENCE when I do something I could not do before</td>
</tr>
<tr>
<td>5</td>
<td>I do SCIENCE because I like learning new things</td>
</tr>
<tr>
<td>6</td>
<td>I do SCIENCE because I enjoy thinking hard</td>
</tr>
<tr>
<td>7</td>
<td>I do SCIENCE because I like to solve hard problems</td>
</tr>
<tr>
<td>8</td>
<td>I do SCIENCE because I enjoy trying to understand new things</td>
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<td>I feel most successful in SCIENCE when I do better than other students</td>
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<td>10</td>
<td>I feel most successful in SCIENCE when I show other students that I am the best</td>
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<tr>
<td>11</td>
<td>I feel most successful in SCIENCE when I do something others cannot do</td>
</tr>
<tr>
<td>12</td>
<td>I feel most successful in SCIENCE when I know more than other students</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>BIOLOGY MOTIVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
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<td>14</td>
<td>I feel most successful in BIOLOGY when I really improve</td>
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<td>I do BIOLOGY because I enjoy trying to understand new things</td>
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<tr>
<td>21</td>
<td>I feel most successful in BIOLOGY when I do better than other students</td>
</tr>
<tr>
<td>22</td>
<td>I feel most successful in BIOLOGY when I show other students that I am the best</td>
</tr>
<tr>
<td>23</td>
<td>I feel most successful in BIOLOGY when I do something others cannot do</td>
</tr>
<tr>
<td>24</td>
<td>I feel most successful in BIOLOGY when I know more than other students</td>
</tr>
</tbody>
</table>
### CHEMISTRY MOTIVATION

<table>
<thead>
<tr>
<th>Rank</th>
<th>Score</th>
<th>Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>60</td>
<td>I feel most successful in CHEMISTRY when I reach personal goals</td>
</tr>
<tr>
<td>26</td>
<td>3</td>
<td>I feel most successful in CHEMISTRY when I really improve</td>
</tr>
<tr>
<td>27</td>
<td>9</td>
<td>I feel most successful in CHEMISTRY when I work to the best of my ability</td>
</tr>
<tr>
<td>28</td>
<td>14</td>
<td>I feel most successful in CHEMISTRY when I do something I could not do before</td>
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<td>20</td>
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<tr>
<td>30</td>
<td>26</td>
<td>I do CHEMISTRY because I enjoy thinking hard</td>
</tr>
<tr>
<td>31</td>
<td>31</td>
<td>I do CHEMISTRY because I like to solve hard problems</td>
</tr>
<tr>
<td>32</td>
<td>35</td>
<td>I do CHEMISTRY because I enjoy trying to understand new things</td>
</tr>
<tr>
<td>33</td>
<td>43</td>
<td>I feel most successful in CHEMISTRY when I do better than other students</td>
</tr>
<tr>
<td>34</td>
<td>48</td>
<td>I feel most successful in CHEMISTRY when I show other students that I am the best</td>
</tr>
<tr>
<td>35</td>
<td>50</td>
<td>I feel most successful in CHEMISTRY when I do something others cannot do</td>
</tr>
<tr>
<td>36</td>
<td>55</td>
<td>I feel most successful in CHEMISTRY when I know more than other students</td>
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### EARTH & ENVIRONMENTAL SCIENCE MOTIVATION

<table>
<thead>
<tr>
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<th>Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>32</td>
<td>I feel most successful in EARTH &amp; ENVIRONMENTAL SCIENCE when I reach personal goals</td>
</tr>
<tr>
<td>38</td>
<td>36</td>
<td>I feel most successful in EARTH &amp; ENVIRONMENTAL SCIENCE when I really improve</td>
</tr>
<tr>
<td>39</td>
<td>41</td>
<td>I feel most successful in EARTH &amp; ENVIRONMENTAL SCIENCE when I work to the best of my ability</td>
</tr>
<tr>
<td>40</td>
<td>44</td>
<td>I feel most successful in EARTH &amp; ENVIRONMENTAL SCIENCE when I do something I could not do before</td>
</tr>
<tr>
<td>41</td>
<td>51</td>
<td>I do EARTH &amp; ENVIRONMENTAL SCIENCE because I like learning new things</td>
</tr>
<tr>
<td>42</td>
<td>4</td>
<td>I do EARTH &amp; ENVIRONMENTAL SCIENCE because I enjoy thinking hard</td>
</tr>
<tr>
<td>43</td>
<td>6</td>
<td>I do EARTH &amp; ENVIRONMENTAL SCIENCE because I like to solve hard problems</td>
</tr>
<tr>
<td>44</td>
<td>10</td>
<td>I do EARTH &amp; ENVIRONMENTAL SCIENCE because I enjoy trying to understand new things</td>
</tr>
<tr>
<td>45</td>
<td>18</td>
<td>I feel most successful in EARTH &amp; ENVIRONMENTAL SCIENCE when I do better than other students</td>
</tr>
<tr>
<td>46</td>
<td>21</td>
<td>I feel most successful in EARTH &amp; ENVIRONMENTAL SCIENCE when I show other students that I am the best</td>
</tr>
<tr>
<td>47</td>
<td>23</td>
<td>I feel most successful in EARTH &amp; ENVIRONMENTAL SCIENCE when I do something others cannot do</td>
</tr>
<tr>
<td>48</td>
<td>27</td>
<td>I feel most successful in EARTH &amp; ENVIRONMENTAL SCIENCE when I know more than other students</td>
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</table>
### PHYSICS MOTIVATION

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>49</td>
<td>24</td>
<td>I feel most successful in <strong>Physics</strong> when I reach personal goals</td>
</tr>
<tr>
<td>50</td>
<td>28</td>
<td>I feel most successful in <strong>Physics</strong> when I really improve</td>
</tr>
<tr>
<td>51</td>
<td>37</td>
<td>I feel most successful in <strong>Physics</strong> when I work to the best of my ability</td>
</tr>
<tr>
<td>52</td>
<td>40</td>
<td>I feel most successful in <strong>Physics</strong> when I do something I could not do before</td>
</tr>
<tr>
<td>53</td>
<td>45</td>
<td>I do <strong>Physics</strong> because I like learning new things.</td>
</tr>
<tr>
<td>54</td>
<td>52</td>
<td>I do <strong>Physics</strong> because I enjoy thinking hard</td>
</tr>
<tr>
<td>55</td>
<td>56</td>
<td>I do <strong>Physics</strong> because I like to solve hard problems</td>
</tr>
<tr>
<td>56</td>
<td>59</td>
<td>I do <strong>Physics</strong> because I enjoy trying to understand new things</td>
</tr>
<tr>
<td>57</td>
<td>7</td>
<td>I feel most successful in <strong>Physics</strong> when I do better than other students</td>
</tr>
<tr>
<td>58</td>
<td>11</td>
<td>I feel most successful in <strong>Physics</strong> when I show other students that I am the best</td>
</tr>
<tr>
<td>59</td>
<td>15</td>
<td>I feel most successful in <strong>Physics</strong> when I do something others cannot do</td>
</tr>
<tr>
<td>60</td>
<td>19</td>
<td>I feel most successful in <strong>Physics</strong> when I know more than other students</td>
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### SCIENCE EDUCATIONAL ASPIRATIONS

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<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>I hope I continue my <strong>Science</strong> studies</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>I want to go on to college or university education to study <strong>Science</strong></td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>I try my best hoping to get into an advanced educational institution to study <strong>Science</strong></td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>I am eager to do some advanced courses in <strong>Science</strong></td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>I hope I continue my <strong>Biology</strong> studies</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>I want to go on to college or university education to study <strong>Biology</strong></td>
</tr>
<tr>
<td>7</td>
<td>13</td>
<td>I try my best hoping to get into an advanced educational institution to study <strong>Biology</strong></td>
</tr>
<tr>
<td>8</td>
<td>15</td>
<td>I am eager to do some advanced courses in <strong>Biology</strong></td>
</tr>
<tr>
<td>9</td>
<td>17</td>
<td>I hope I continue my <strong>Chemistry</strong> studies</td>
</tr>
<tr>
<td>10</td>
<td>19</td>
<td>I want to go on to college or university education to study <strong>Chemistry</strong></td>
</tr>
<tr>
<td>11</td>
<td>21</td>
<td>I try my best hoping to get into an advanced educational institution to study <strong>Chemistry</strong></td>
</tr>
<tr>
<td>12</td>
<td>23</td>
<td>I am eager to do some advanced courses in <strong>Chemistry</strong></td>
</tr>
<tr>
<td>13</td>
<td>25</td>
<td>I hope I continue my <strong>Earth &amp; Environmental Science</strong> studies</td>
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<tr>
<td>14</td>
<td>27</td>
<td>I want to go on to college or university education to study <strong>Earth &amp; Environmental Science</strong></td>
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<tr>
<td>15</td>
<td>30</td>
<td>I try my best hoping to get into an advanced educational institution to study <strong>Earth &amp; Environmental Science</strong></td>
</tr>
<tr>
<td>16</td>
<td>31</td>
<td>I am eager to do some advanced courses in <strong>Earth &amp; Environmental Science</strong></td>
</tr>
<tr>
<td>17</td>
<td>33</td>
<td>I hope I continue my <strong>Physics</strong> studies</td>
</tr>
<tr>
<td></td>
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<tr>
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<tr>
<td><strong>CAREER ASPIRATIONS</strong></td>
<td></td>
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<tr>
<td>21</td>
<td>20</td>
<td>I wish to get a good job in <strong>SCIENCE</strong></td>
</tr>
<tr>
<td>22</td>
<td>22</td>
<td>I very much hope to get a good paying <strong>SCIENCE</strong> job when I am employed</td>
</tr>
<tr>
<td>23</td>
<td>24</td>
<td>I hope I will find desirable employment in the future in <strong>SCIENCE</strong></td>
</tr>
<tr>
<td>24</td>
<td>26</td>
<td>I wish to get a good job in <strong>BIOLOGY</strong></td>
</tr>
<tr>
<td>25</td>
<td>28</td>
<td>I very much hope to get a good paying <strong>BIOLOGY</strong> job when I am employed</td>
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<td>26</td>
<td>29</td>
<td>I hope I will find desirable employment in the future in <strong>BIOLOGY</strong></td>
</tr>
<tr>
<td>27</td>
<td>2</td>
<td>I wish to get a good job in <strong>CHEMISTRY</strong></td>
</tr>
<tr>
<td>28</td>
<td>34</td>
<td>I very much hope to get a good paying <strong>CHEMISTRY</strong> job when I am employed</td>
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<td>I hope I will find desirable employment in the future in <strong>CHEMISTRY</strong></td>
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<tr>
<td>30</td>
<td>8</td>
<td>I wish to get a good job in <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong></td>
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<tr>
<td>31</td>
<td>10</td>
<td>I very much hope to get a good paying <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong> job when I am employed</td>
</tr>
<tr>
<td>32</td>
<td>12</td>
<td>I hope I will find desirable employment in the future in <strong>EARTH &amp; ENVIRONMENTAL SCIENCE</strong></td>
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<tr>
<td>33</td>
<td>14</td>
<td>I wish to get a good job in <strong>PHYSICS</strong></td>
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<tr>
<td>35</td>
<td>18</td>
<td>I hope I will find desirable employment in the future in <strong>PHYSICS</strong></td>
</tr>
</tbody>
</table>
Appendix B

Letter of Invitation to School Principals

Educational Excellence and Equity (E³) Research Program
Centre for Educational Research
University of Western Sydney
Bankstown Campus, Building 19
Locked Bag 1797
Penrith South DC NSW 2751

12th September 2011

Dear Principal,

Research study on Students’ Science Self-concepts, Motivation, Aspirations and Achievement in High School Science and Chemistry

We wish to invite your school to participate in the above research study conducted by the University of Western Sydney (UWS). The purpose of this study is to investigate the relationship between Students’ Science Self-concepts, Motivation, Aspirations and Achievement in High School Science and Chemistry.

Research tells us that secondary students are not pursuing further study and careers in the science field. This study seeks to gather data to help address this problem in the future. If your school chooses to participate, you will receive a report which outlines our findings in this matter. This information may assist you in developing your science programs further.

Your participation would involve:
- Distributing a letter of invitation (see attachment 1) to your students in Year 7-12 studying science subjects to seek their permission for their child to be involved in the study.
- Allowing members of the research team to enter into your school at a time convenient to yourself and, to have all the above students taken into the assembly hall to complete a 30-40 minute survey. A portion of these students will also be invited to participate in a 30 minute small group focus interview on a later day.
- Distributing a letter of invitation (see attachment 2) to your science teachers to consider participating in a 15 minute interview to ascertain their views on the above research topic; and
- Asking teachers to complete a rating of students’ achievement in science (approximately 30 seconds per student).

This research project has been approved by the State Education Research Approval Process (SERAP No.2011133). The survey will be conducted with all students in a hall during school time. The interviews will be conducted after receiving the responses for the questionnaires and we hope to collect data in the third term of school calendar this year.

Your assistance in this study is voluntary. There will be no adverse consequences should you choose not to assist. You may also withdraw your involvement in the study at any time. Information provided in this study by individuals will not be given to others. However, you will be made aware of the name of any student who discloses information which impacts on their safety or wellbeing so that you can determine an appropriate response consistent with NSW DEC policies and practices. Any results that are reported in research reports will be
reported in group form, without identifying individuals or the school. The data will be kept in a locked file, accessible only to the university researchers in this study, although the unidentified data may be further analysed by other university researchers. The results of the study will be reported back to your school and especially the science educators in your school will be benefitted with greater understanding of the relations between students’ science self-concepts, motivation, aspirations, and achievement in different domains in science across gender and age levels.

Please indicate on the attached form your decision and return it to Professor Rhonda Craven (Fax: 02 9772 6193)

This research is being conducted by:-

- Professor Rhonda Craven, University of Western Sydney (97726557, r.craven@uws.edu.au);
- Dr. Danielle Tracey, UWS (97726105, d.tracey@uws.edu.au);
- Dr. Anthony Dillon, UWS (97726202, a.dillon@uws.edu.au);
- Wanasinghe Chandrasena (97726145; 16910254@student.uws.edu.au) (PhD candidate).

Please contact me if you have any further questions relating to the study or one of the researchers. We do hope your school is interested in assisting us with this important project.

Yours sincerely,

Professor Rhonda Craven
Centre for Educational Research, University of Western Sydney

NOTE: This study has been approved by the University of Western Sydney Human Research Ethics Committee (Approval No. H9209). If you have any complaints or reservations about the ethical conduct of this research, you may contact the Ethics Committee through the Research Ethics Officers (Tel: 02 47 360 883). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Principal Consent Form

Research study on Students’ Science Self-concepts, Motivation, Aspirations and Achievement in High School Science and Chemistry

I, ……………………………………………………………, consent for my school ………………………………………………………… to participate in the research project titled “Students’ Science Self-concepts, Motivation, Aspirations and Achievement in High School Science and Chemistry”.

I acknowledge that:

I have read the participant information sheet and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

The procedures required for the project and the time involved have been explained to me, and any questions I have about the project have been answered to my satisfaction.

School Name ______________________________________

Principal Name ______________________________________

Signature ___________________________ Date__________

PLEASE RETURN THIS FORM TO FAX No: 02 9772 6193

If you prefer to mail this, an addressed envelope has also been included to return your consent form to us.

Note: This study has been approved by the UWS Human Research Ethics Committee and the NSW Department of Education. This study has been approved by the University of Western Sydney Human Research Ethics Committee (Approval No. H9209). If you have any complaints or reservations about the ethical conduct of this research, you may contact the Ethics Committee through the Research Ethics Officers (Tel: 47 360 883). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Appendix C

Letter of Invitation to School Teachers

Educational Excellence and Equity (E³) Research Program
Centre for Educational Research
University of Western Sydney
Bankstown Campus, Building 19
Locked Bag 1797
Penrith South DC NSW 2751

12th September 2011

Dear Teacher,

Research study on Students’ Science Self-concepts, Motivation, Aspirations and Achievement in High School Science and Chemistry

We wish to invite you to participate in the above research study conducted by the University of Western Sydney (UWS). The purpose of this study is to investigate the relationship between Students’ Science Self-concepts, Motivation, Aspirations and Achievement in High School Science and Chemistry.

Your participation would involve:
- Completing a 30 minute interview to ascertain your views on the above research topic;
- Completing a rating scale of students’ achievement in science for each student participating in the research. This will take approximately 30 seconds for each student.

This research project has been approved by the State Education Research Approval Process (SERAP No.2011133). We hope to collect data in the third term of school this year. Interviews can be conducted either face-to-face in the school premises or on the phone by request, at a time convenient to you.

Your participation in this study is voluntary. There will be no adverse consequences should you choose not to participate. You may also withdraw from the study at any time. Information provided in this study by individuals remains confidential. Results that are reported in research reports will be reported in group form, without identifying individuals or the school. The data will be kept in a locked file, accessible only to the university researchers in this study, although the unidentified data may be further analysed by other university researchers. The results of the study will be reported back to your school and your school will be benefitted with greater understanding of the relations between students’ science self-concepts, motivation, aspirations, and achievement in different domains in science across gender and age levels.

Please contact me if you have any further questions relating to the study. Please indicate if you wish to participate on the attached form and return it via either fax or mail.
This research is being conducted by:-

- Professor Rhonda Craven, University of Western Sydney (97726557, r.craven@uws.edu.au);
- Dr. Danielle Tracey, UWS (97726105, d.tracey@uws.edu.au);
- Dr. Anthony Dillon, UWS. (97726202, a.dillon@uws.edu.au);
- Wanasinghe Chandrasena (97726145; 16910254@student.uws.edu.au) (PhD candidate).

Yours sincerely,

Professor Rhonda Craven
Centre for Educational Research, University of Western Sydney

NOTE: This study has been approved by the University of Western Sydney Human Research Ethics Committee (Approval No. H9209). If you have any complaints or reservations about the ethical conduct of this research, you may contact the Ethics Committee through the Research Ethics Officers (Tel: 02 47 360 883). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Teacher Consent Form
Research study on Students’ Science Self-concepts, Motivation, Aspirations and Achievement in High School Science and Chemistry

I,………………………………………………., consent to participate in the research project titled “Students’ Science Self-concepts, Motivation, Aspirations and Achievement in High School Science and Chemistry”.

I acknowledge that:

I have read the participant information sheet and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

The procedures required for the project and the time involved have been explained to me, and any questions I have about the project have been answered to my satisfaction.

I consent to the audio taping of the interviews to be held with me. I understand that my involvement is confidential and that the information gained during the study may be published but no information about me will be used in any way that reveals my identity.

I understand that I can withdraw from the study at any time, without affecting my relationship with the researcher/s now or in the future.

School Name  _______________________________________
Teacher Name  _______________________________________
Signature  ______________________________________ Date________________

PLEASE RETURN THIS FORM EITHER BY FAX (No: 02 9772 6193) OR IN THE ENVELOPE PROVIDED BY XXXXXX/2011.

Note: This study has been approved by the UWS Human Research Ethics Committee and the NSW Department of Education. This study has been approved by the University of Western Sydney Human Research Ethics Committee (Approval No. H9209). If you have any complaints or reservations about the ethical conduct of this research, you may contact the Ethics Committee through the Research Ethics Officers (Tel: 47 360 883). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Appendix D
Letter of Invitation to Parents

Educational Excellence and Equity ($E^3$) Research Program
Centre for Educational Research
University of Western Sydney
Bankstown Campus
Locked bag 1797, Penrith
NSW 2751

12.09.2011

Dear Parent / Guardian,

Research study on Students’ Science Self-concepts, Motivation, Aspirations and Achievement in High School Science and Chemistry

We wish to invite your child to participate in the above research study conducted by the University of Western Sydney (UWS). There is a steady decline of student enrolments in Science Education in Australia. As such, the purpose of this study is to investigate the relations between Students’ Science self-concepts, motivation, aspirations, and achievement in High School Science and Chemistry. This research project has been approved by the State Education Research Approval Process (SERAP No. 2011133). Participation is voluntary, and would involve your child completing a 30-40 minute survey on their views about school science subjects. Some children will also be invited to participate in 15 minute small group interview at school with trained research assistants to collect their perceptions about science. We will also ask your child’s science teacher to rate your child’s ability in science.

More details about the research are outlined on the next page. If you are willing for your child to participate in this research, please fill out the consent form below, tear it off, and return it to your child’s teacher or fax to Dr Evelyn Hibbert from the University of Western Sydney (Fax: 02 9772 6193).

Yours sincerely,

Professor Rhonda Craven
Centre for Educational Research, University of Western Sydney
Locked Bag 1797, Penrith, NSW 2751, Australia.
Telephone: 02 9772 6557; Fax: 02 9772 6193; Email: r.craven@uws.edu.au
CONSENT FORM

Research study on Students’ Science Self-concepts, Motivation, Aspirations and Achievement in High School Science and Chemistry

I acknowledge that I have read the “Research study on Students’ Science Self-concepts, Motivation, Aspirations and Achievement in High School Science and Chemistry Additional Information Sheet” and that I have discussed the project with my child. I give consent for the participation of my child for the above research project.

I am aware that, according to the Department of Education and Communities (DEC) procedures, researchers are required to inform the Principal if my child is identified as being at risk of harm from him/herself or others during participation in this research project and give consent for the researchers to notify the Principal of this.

Parent/Guardian Name (please print) ________________________________

Parent/Guardian Signature ________________________________

Your Child’s name (family name) _______________
(first name) _______________

Your Child’s school ____________________________________________

Please return to your child’s teacher or fax to Evelyn Hibbert (Fax: 02 9772 6193).
Research study on Students’ Science Self-concepts, Motivation, Aspirations and Achievement in High School Science and Chemistry

Additional Information Sheet

Aim

The aim of this study is to investigate the relations between Students’ Science self-concepts, motivation, aspirations and achievement in High School Science and Chemistry.

Participation

Participation is completely voluntary. Participation for your child will involve taking part in completing a 30-40 minute survey on their views about school science subjects. Some children will also be invited to complete a 15 minute taped small group interview at school with trained research assistants to collect their perceptions about science. We will also ask your child’s science teacher to rate your child’s ability in science.

Nature of Participation

Your assistance in this study, and your child’s, is voluntary. There will be no adverse consequences should you or your child choose not to assist. You may also withdraw your child’s involvement in the study at any time. Information provided in this study by individuals will not be given to others. However, researchers are required by the Department of Education and Communities to ensure that “when studies have the potential to identify students as being at risk of harm from themselves or others, then the names of such students will need to be disclosed to the relevant school principal(s) to enable further action to be taken as may be appropriate. The Department acknowledges that this requirement may jeopardise confidentiality and may present methodological problems. In such situations, however, it considers its 'duty of care' obligations to be paramount” (NSW Department of Education and Training, State Education Research Approval Process, Guidelines for Approving Applications from External Agencies to Conduct Research in NSW Government Schools, 2006, p. 14). In the unlikely event that a student should feel any sort of discomfort or concern as a result of participation they can meet with the school counsellor.

Results

Results in research reports will be reported in group form, without identifying individuals or schools. The data will be kept in a locked file, accessible only to the university researchers in this study, although the unidentified data may be further
analysed by other university researchers. The results of the study will be reported back to your school.

**Researchers**

- Professor Rhonda Craven, University of Western Sydney (97726557, r.craven@uws.edu.au);
- Dr. Danielle Tracey, UWS (97726105, d.tracey@uws.edu.au);
- Dr. Anthony Dillon, UWS. (97726202, a.dillon@uws.edu.au);
- Wanasinghe Chandrasena (97726145; 16910254@student.uws.edu.au) (PhD candidate).

Please contact the researchers if you require any further information.

NOTE: This study has been approved by the University of Western Sydney Human Research Ethics Committee (Approval No. H9209). If you have any complaints or reservations about the ethical conduct of this research, you may contact the Ethics Committee through the Research Ethics Officers (Tel: 02 47 360 883). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Appendix E

Tables of Pearson Correlations

Table E-1

*Standardised Correlations for the MIMIC Model of SSDQ across Gender and Year*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Gender</th>
<th>Year Level</th>
<th>Gender*Year (Interaction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Science</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$r$</td>
<td>.107*</td>
<td>.156*</td>
</tr>
<tr>
<td>Biology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$r$</td>
<td>-.043</td>
<td>.276**</td>
</tr>
<tr>
<td>Chemistry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$r$</td>
<td>.140*</td>
<td>.046</td>
</tr>
<tr>
<td>Earth &amp; Environmental Science</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$r$</td>
<td>-.003</td>
<td>-.028</td>
</tr>
<tr>
<td>Physics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$r$</td>
<td>.198**</td>
<td>-.100</td>
</tr>
</tbody>
</table>

*Note.* All parameter estimates are presented in completely standardized format.

$r =$ Pearson Correlation,

* = All factor loadings are significant at $p < .05$,

** = All factor loadings are significant at $p < .01$. 
Table E-2  

*Standardised Correlations for the MIMIC Model of SMQ across Gender and Year*

<table>
<thead>
<tr>
<th>Beta coefficients and correlations</th>
<th>Gender Level</th>
<th>Year Level</th>
<th>Gender*Year (Interaction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mastery Motivation</td>
<td>r</td>
<td>-.069</td>
<td>.116</td>
</tr>
<tr>
<td>Intrinsic Motivation</td>
<td>r</td>
<td>.044</td>
<td>.069</td>
</tr>
<tr>
<td>Ego Motivation</td>
<td>r</td>
<td>.008</td>
<td>.015</td>
</tr>
</tbody>
</table>

*Note.* All parameter estimates are presented in completely standardized format.

$r$ = Pearson Correlation,  
* = All factor loadings are significant at $p < .05$,  

Table E-3

Standardised Correlations for the Structural Equation Model of the Gender, Year, and Science Self-concepts for Predicting Students’ Science Aspirations, Career Aspirations, and Science Achievement

<table>
<thead>
<tr>
<th></th>
<th>GN</th>
<th>YR</th>
<th>GS</th>
<th>BG</th>
<th>CH</th>
<th>EE</th>
<th>PH</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA</td>
<td>.00</td>
<td>.14</td>
<td>.50</td>
<td>.52</td>
<td>.47</td>
<td>.34</td>
<td>.49</td>
</tr>
<tr>
<td>CA</td>
<td>-.03</td>
<td>.16</td>
<td>.41</td>
<td>.42</td>
<td>.35</td>
<td>.32</td>
<td>.43</td>
</tr>
<tr>
<td>TR</td>
<td>-.05</td>
<td>-.05</td>
<td>.27</td>
<td>.33</td>
<td>.26</td>
<td>.17</td>
<td>.16</td>
</tr>
<tr>
<td>SR</td>
<td>-.02</td>
<td>-.02</td>
<td>.71</td>
<td>.52</td>
<td>.56</td>
<td>.47</td>
<td>.42</td>
</tr>
</tbody>
</table>

*Note.* All parameter estimates are presented in completely standardized format.

Of the SSDQ self-concept factors, 
SA = Science Aspirations, CA = Career Aspirations, TR = Teacher Ratings, SR = Student Ratings, 
GN= Gender, YR= Year, GS = General Science, BG = Biology, CH = Chemistry, 
EE = Earth and Environmental Science, PH = Physics, $r$ = Pearson Correlation.
Table E-4

*Standardised Correlations for the Structural Equation Model of the Gender and Year with Science Motivation for Predicting Students’ Science Aspirations, Career Aspirations, and Science Achievement*

<table>
<thead>
<tr>
<th></th>
<th>Beta Coefficients and Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gender</td>
</tr>
<tr>
<td>Science Aspirations</td>
<td></td>
</tr>
<tr>
<td>$r$</td>
<td>.05</td>
</tr>
<tr>
<td>Career Aspirations</td>
<td></td>
</tr>
<tr>
<td>$r$</td>
<td>.01</td>
</tr>
<tr>
<td>Teacher Ratings</td>
<td></td>
</tr>
<tr>
<td>$r$</td>
<td>-.04</td>
</tr>
<tr>
<td>Student Ratings</td>
<td></td>
</tr>
<tr>
<td>$r$</td>
<td>.04</td>
</tr>
</tbody>
</table>

*Note.* All parameter estimates are presented in completely standardized format.

$r = Pearson Correlation.$